THE ENGINEER

A Seven-Day Journal

British Electricity Authority's Annual Report

The third annual report of the British Electricity Authority, published yesterday, shows that the combined revenues of the Authority and the area electricity boards, in the year ended March 31, 1951, exceeded their combined outgoings on revenue account by £6,330,000. This surplus relates to a turnover of £237 million, and compares with surpluses of £4,390,000 in 1948–49 and £7,160,000 last year. At March 31st last, the installed capacity of the 289 power stations owned by the Authority was 14,592MW, and the total output capacity, assuming all plant in service, was 13,156MW. New plant brought into service during the year gave an additional output capacity of 918MW, but, allowing for the shutting down of some unserviceable plant, the net increase in output capacity was 819MW. During 1950–51 three new power stations—Croydon "B," Agecroft (Salford) and Poole—were brought into partial operation. At the end of the period covered by the report, there were forty-three new power stations and thirty-one extensions to existing stations under construction or planned in the programmes up to and including that for 1956. The maximum potential demand on the electricity supply system occurred on December 18, 1950, and was estimated at 13,448MW, which was 1166MW higher than in the previous year. The overall thermal efficiency of steam plants showed an improvement from 21·33 per cent in 1949–50 to 21·54 in 1950–51. Coal consumption per unit of electricity generated showed a corresponding fall from 1·468 lb to 1·447 lb. The major transmission schemes put in hand during the year included 265 route miles of 132kV overhead lines, and about 371 route miles of the new 275kV grid, between West Melton (Sheffield) and Clyde's Mill (Glasgow), and between Tilbury and Elstree. To meet the rapidly growing load and to strengthen existing distribution arrangements twenty-three new grid points of supply to area boards were agreed upon.

The Royal Yacht

It has been announced by the Admiralty that a second hospital ship is to be included in the Navy Estimates for 1951 and that this medium-sized vessel, which it is planned to build under the new construction programme, will be used by the King, in times of peace, as a Royal yacht. The proposal is a revival of the plan to replace the "Victoria and Albert" by building a new Royal yacht, an item which appeared in the 1939 Navy Estimates and which was dropped due to the outbreak of war. Even in 1939 the "Victoria and Albert" was overdue for replacement, the ship being then forty years old. Built in 1899, the yacht, which is no longer seagoing, has a length between perpendiculars of 380ft, a beam of 40ft, a mean draught of 18ft, and a displacement of 4700 tons. The machinery consists of two sets of triple-expansion engines, taking steam from eighteen coal-fired Belleville boilers and developing a total of 11,800 i.h.p., sufficient to give the ship, when new, a speed of 20 knots. The building of the proposed dual-purpose ship, which will be probably about 5000 tons displacement and be built by contract, has much to recommend it, since the design features of a yacht and a hospital ship have much in common. Conversion from peacetime duties to the wartime role of hospital ship can be effected with the minimum of difficulty, since both services have similar requirements regarding accommodation. The large ceremonial State compartments are the counterpart of the hospital wards and the Royal suite is suitable for conversion into operating theatres, while the cabins occupied by Court officials can be used by the ship's medical staff. It is felt that it is fitting that the King should have a Royal yacht at his command, instead of temporary accommodation having to be prepared in a vessel owned by one of the liner companies, and that no objection can be made on the score of economy, since the yacht will be readily available to the Navy should the need arise.

Conference on the Fuel and Power Shortage

A conference on "Meeting the Fuel and Power Shortage," which was organised by the Combustion Engineering Association, was held in London on Tuesday and Wednesday last, there being a large attendance on both days. Mr. P. A. Sanders, president of the Association, was in the chair at the opening session on Tuesday morning, when the Minister of Fuel and Power, Mr. P. Noel-Baker, addressed the conference. In the course of his speech the Minister said that home coal consumption was now running at an annual rate of 210,000,000 tons, and this year it was expected that it would be nearly 20,000,000 tons higher than it was in 1948. It was essential to get 10,000 more men for the mines by the end of January and 20,000 by the end of April. The chairman of the National Coal Board, Sir Hubert Houldsworth, K.C., also spoke on Tuesday morning, stating that in the last eight weeks 1,600,000 tons more coal had been raised than in the corresponding period of last year. He gave a warning, however, that extra coal output from Saturday working could not be pushed much higher. What was necessary to help relieve the shortage, Sir Hubert said, was a "combined operation," with industry playing its part in the more efficient use of fuel. Among the speakers on Tuesday afternoon, when Sir John Charrington presided, was Sir Archibald Forbes, president of the Federation of British Industries, who dealt with industry's fuel problems. Commenting on the "cramping shortage" of fuel and power each year since the end of the war, Sir Archibald said that in the industrial field such shortages not only operated directly to curtail production, but had serious consequential effects. They dislocated factory organisation, diverted thought and energy to the evolution of stopgap measures, and generally undermined the confidence both of producers and customers. He expressed the hope that fuel economy would receive special attention from boards of directors and that every encouragement would be given by them to their technical staffs. With the price of industrial coal ranging from three to three and a half times the pre-war level, Sir Archibald observed, coal was expensive as well as being scarce, and fuel economy could make a significant contribution towards reduced cost of production. The programme for Wednesday included addresses on "The Short-Term Economy," by Mr. B. E. A. Vigers; "The Long-Term Economy," by Mr. Oliver Lyle; and on "The Requirements for a National Fuel Policy," by Sir Ewart Smith.

N.C.B. Coking Plant at Wingerworth

The National Coal Board is to erect a new coking plant in its East Midlands division at Wingerworth, near Chesterfield. It will be known as the Avenue coking plant, and will be the biggest owned by the Board. The total capital cost of the new plant is estimated at about £8,000,000, and the main contract—valued at £4,750,000—for the construction work has been placed with the Woodall-Duckham Company, Ltd. It is the largest single contract so far placed by the Coal Board. The installation will consist of 106 ovens, which will carbonise over 750,000 tons of coal a year, producing 500,000 tons of coke and large quantities of town gas, which will be sold to the gas industry for local distribution. In addition to extensive coal blending facilities and the normal primary by-product plant associated with modern carbonisation practice, the project provides for a benzole rectifying plant, tar distilling plant, gas purifying equipment, and a sulphuric acid plant. It is expected that about 3,000,000 gallons of crude benzole and 6,000,000 gallons of crude tar will be produced annually. The National Coal Board has given an undertaking to the Government to maintain the output of oven coke, and the Avenue plant, it is stated, is part of the Board's extensive programme for developing its carbonisation activities.

The South Bank Exhibition Site

The London County Council has issued a statement this week on the permanent development of the South Bank of the Thames, following the closing of the Festival of Britain exhibition. It says that the Council desires, so far as economic conditions permit, to take full advantage of any amenities created by the Festival and of the public interest which has been aroused in the better use of the South Bank as a whole. The L.C.C. scheme provides for full public enjoyment of the new embankment, and the views of London which it affords, by creating a riverside garden along the exhibition frontage, from County Hall to Waterloo Bridge, which is to be a memorial to the people of London who lost their lives in the second world war. The skylon will be removed during the coming winter, together with such other features as are not required to be kept as amenities. The section behind the riverside garden, between County Hall and Hungerford Bridge, is intended ultimately for Government offices and conference halls. The Royal Festival Hall is to be completed as soon as conditions permit, and the site adjoining it is that for the National Shakespeare Memorial Theatre, the foundation stone of which was laid by H.M. the Queen last July. As regards the parts of the exhibition site not to be redeveloped for some time owing to economic restrictions, mainly lying between the Royal Festival Hall and the new Waterloo Road/York Road roundabout, negotiations are in progress as to the practicability of retaining until permanent redevelopment necessitates their removal, the Lion and Unicorn pavilion, the administration buildings, the Telecinema, and possibly other exhibition buildings. Immediately beyond Waterloo Bridge is a further area in the ownership partly of the Council and partly of the Duchy of Cornwall. Negotiations have been proceeding for some time for the acquisition of this key site to accommodate the British Science Centre, a decision to establish which was announced in Parliament in November 1950. It is hoped that a "New Burlington House," on the river front facing Somerset House, shall form the new home of the Royal Society and fifteen other leading scientific learned societies. Other buildings will house Government scientific organisations, including the Patent Office and its library, which will be modernised and extended as a central reference library of science and technology. The L.C.C. statement emphasises, of course, that the rate of fulfilment of these permanent schemes is dependent on the international situation and on economic and financial conditions.

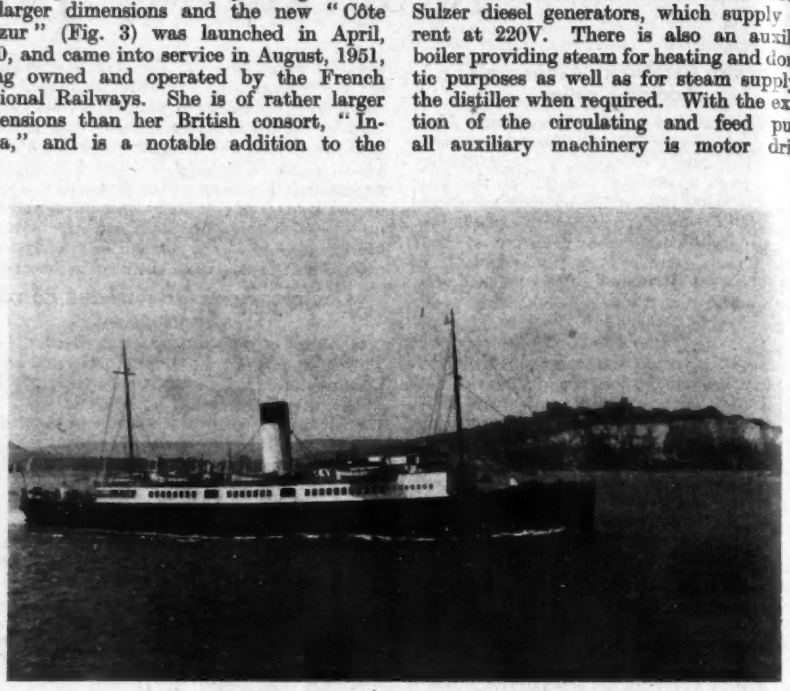
The French Cross-Channel Ship "Cote d'Azur"

By G. W. TRIPP, O.B.E., F.C.G.I., M.I.C.E.

FOR upwards of half a century the French have been responsible for the afternoon passenger service between Calais and Dover, for, by an arrangement made in 1896, the French Northern Railway maintained the sailings with two steamers chartered from the London, Chatham and Dover Railway. In 1898 two notable paddle steamers were built and engined by the Ateliers et Chantiers de la Loire, of St. Nazaire. "Le Nord" and "Le Pas de Calais" were handsome vessels, as may be seen by our illustration of the latter, below. They were larger than their English sisters, having the following dimensions: length, 337·8ft; breadth, 34·9ft; depth, 14·2ft; tonnage, 1541 gross. They were driven by triple expansion engines having cylinders 41in, 59in and 87in diameter and a stroke of 89in. With a speed of 21½ knots, they were among the fastest cross-channel steamers of their day and they had the distinction of being the last paddle steamers to ply regularly between Britain and the Continent. Unfortunately, "Le Nord" was wrecked off the South Foreland in 1923 and her sister was sold the following year. History repeated itself for again the French had resource to English railways and took over from the Southern Railway two triple-screw turbine steamers.

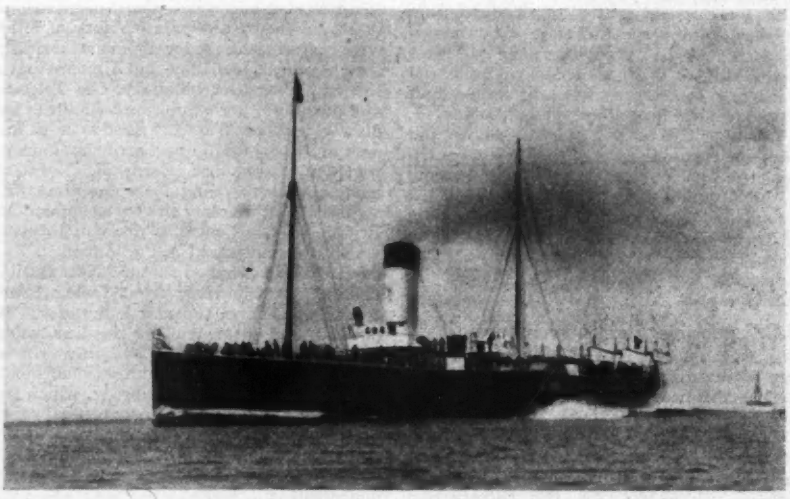
In 1932 two new steamers were built by the Forges et Chantiers de la Méditerranée, of Havre, and once more these were bigger than their English contemporaries, for the sister ships, "Côte d'Azur," illustrated herewith, and "Côte d'Argent," had the following leading dimensions: length, 325·8ft; breadth, 45ft; depth, 26ft; tonnage, 3047 gross. Their twin screws were driven by four single-reduction-geared turbines and they had a speed of 23 knots. Both of these vessels found favour with the travelling public, but their careers were brief, for, in 1940, "Côte d'Azur" was taken over by the French Navy for transport of troops and later she took part in the evacuation of British troops from Dunkirk, where she was sunk by air attack in May, 1940. She was refloated by the Germans and used as a minelayer but eventually became a war casualty, as also did her sister.

The French Ministry of Shipping decided to make good these losses by a single vessel of larger dimensions and the new "Côte d'Azur" (Fig. 3) was launched in April, 1950, and came into service in August, 1951, being owned and operated by the French National Railways. She is of rather larger dimensions than her British consort, "Invicta," and is a notable addition to the cross-channel steamers on the shorter sea routes to the Continent.



THE FIRST "COTE D'AZUR"

Her leading dimensions are: length, overall, 365ft; between perpendiculars, 348ft; breadth, overall, 50ft 7in; mean draught, 12ft 4in; loaded displacement, 3012 tons. The vessel is propelled by two sets of geared turbines, each of which has a high pressure, a low pressure and an astern turbine. Steam is supplied by the two main boilers, which were built by the Forges et Chantiers de la Méditerranée, and work at a pressure of 425 lb per square inch. They have a heating surface of 8396 square feet with an evaporation of about 134,000 lb per hour each, at a superheat temperature about 700 deg. Fah. These boilers are provided with air preheaters, the air being supplied by two turbo fans. The two lines of main shafting between the turbine gearboxes and the twin screws are supported in SKF bearings. The machinery is installed in three compartments, the after one containing the main turbines and the forward one being the boiler-room, while in the centre one will be found three 300kW Sulzer diesel generators, which supply current at 220V. There is also an auxiliary boiler providing steam for heating and domestic purposes as well as for steam supply to the distiller when required. With the exception of the circulating and feed pumps all auxiliary machinery is motor driven.



PADDLE STEAMER "LE PAS DE CALAIS"

Developing an i.h.p. of 22,000, a speed of 24 knots is attained, but that of 25·5 knots has been reached, and it is of particular interest that while British Railways seem content to reduce the speed on the Irish mail services to 21 knots, the French have had the courage to place on the shorter sea route a ship with a higher speed than that formerly obtaining. Even if a lower speed is normally considered sufficient, the higher speed should prove invaluable when conditions are adverse, and enable the scheduled time to be kept at all times.

The practice of entering harbour stern first seems to have come to stay in spite of the protests of bad sailors, who find the manœuvring at the end of the passage particularly trying, and a bow rudder is provided to facilitate astern operation. This rudder, as well as the main one aft, is telemotor controlled and as a safety precaution twin electric motors have been installed. Provision has been made for anchoring and mooring forward by two combined vertical spindle windlasses and capstans, which are driven by electric motors situated below deck. There are two capstans aft similar to the forward ones, except that they are without cable lifters. Ward Leonard booster control has been provided to ensure flexibility of operation.

As regards the actual construction of the vessel, it has been built to the requirements of the Bureau Veritas and is in line with the agreements of the London Convention of 1948, dealing with safety of life at sea, and also with the Seattle Conference, regarding the accommodation to be provided for the crew. The hull has been subdivided to comply with present-day requirements in case flooding should occur. Welding has been resorted to wherever possible, particularly in the case of deck construction, and the

plating above the main deck, but below this, while the butts are welded, the longitudinal seams are riveted.

The passenger accommodation for the 1450 carried is of a high standard, every attention having been given to the comfort of the passenger, and the decoration of the saloons is modern in style. The lettering of the decks is different from that usually obtaining on British steamers in that "D" deck is the one beneath the bridge. On the bridge deck forward is a spacious wheelhouse equipped with all modern aids to navigation, including radar, echo sounder and radio direction finder. Wireless telegraphy and telephony, a public address system and internal telephone communication are provided. The captain's quarters

Coming to the main, or "C" deck, there is a spacious first-class smoking room and bar forward, while astern is a third-class lounge and bar and between them a large promenade lounge, having liberal seating (this is clearly shown in our illustration), and with fourteen cabines de luxe opening on to it. These and the two cabines de grand luxe are furnished with individual telephones. Passport and other offices are also situated on this deck, as well as ample toilet provision.

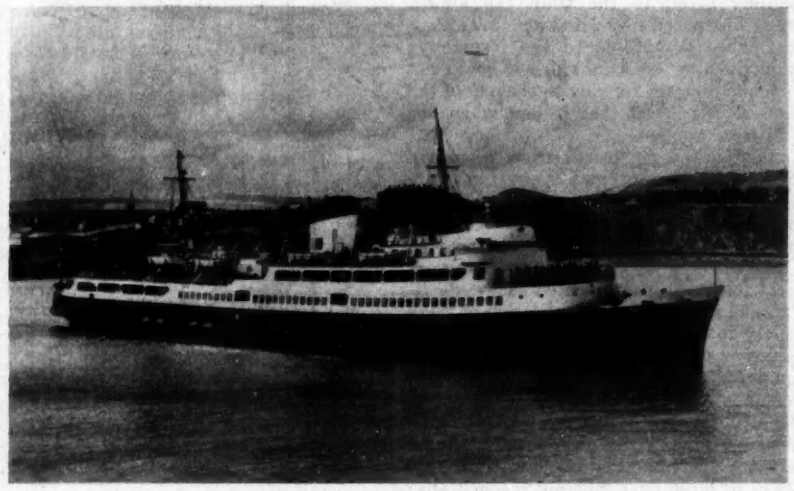
On the "B" deck forward is the first-class dining saloon, with seating for 100 passengers and astern a third-class dining saloon accommodating thirty-two persons, this saloon being on the starboard side of the ship, while opposite on the port side is

When about to cross on this ship the first thing to attract attention was the modern form of outline, but the shape of funnel is unusual and can hardly be said to add to the good looks of the vessel; it is, however, the result of considerable experiment and has been designed to keep the smoke from beating down on the decks. With a view

PART OF COVERED PROMENADE DECK

to obtaining similar results it may be remembered that her English sister, "Maid of Orleans," was provided with a covered top to the inner funnel, which increases the velocity with which the gases are ejected, thereby forcing them sufficiently high to avoid the area of low pressure immediately behind the funnel, thus allowing the funnel to be on more orthodox lines. It will be interesting to learn which gives the better results. The next noticeable feature was the smooth running of the turbines, for when seated in the dining saloon before sailing the actual time of leaving the quay at Calais was not noticed. On arrival at Folkestone, "Côte d'Azur" berthed immediately beyond "Maid of Orleans," thus enabling the general outlines of the two vessels to be compared. Certainly both are excellent examples of modern practice, the new ship setting a standard that will not be easy to better.

Comparing the new ship with her namesake, it is worthy of note that whereas the horsepower of the former vessel was 13,000, that of the new one is 22,000, and the electrical power available has been increased from 500kW to 1000kW for, in addition to the three 300kW sets which have already been mentioned, there is also an emergency generator of 100kW capacity on the new vessel.



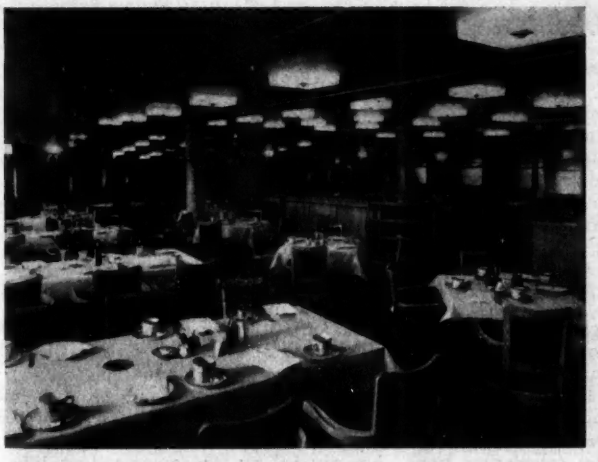
THE NEW TURBINE STEAMSHIP "COTE D'AZUR"

are immediately astern of the wheelhouse and are spacious and comfortable, and then come the officers' quarters. There are four lifeboats on this deck.

On the next, the boat or "D" deck, working from bows to stern, will be found a large tea room, capable of seating forty persons and with large windows affording an uninterrupted view. The tea room, a recognised feature on the Clyde passenger steamers, is somewhat of an innovation on a cross-channel vessel, but should prove to be a definite asset; then there are two cabines de grand luxe, tastefully laid out and decorated. Four more lifeboats and the ship's lifebelts are accommodated on this deck.

a spacious ladies' saloon. Amidships are the engineers' quarters, which are easily accessible from the engine-room. On this deck is the officers' mess, other messes and the cook's galley, where everything is cooked electrically.

The only passenger accommodation on "A" deck consists of two first-class saloons; one for ladies, the other for gentlemen. The rest of this deck is for crew's quarters, a baggage hold and a motor-car park. The bottom deck, that below the "A" deck, has engine-room and boiler-house amidships and astern of the engine-room a sizeable workshop, while forward is storage for oil, fresh water, ballast, &c.



FIRST CLASS DINING SALOON

FIRST CLASS BAR AND SMOKING ROOM

Assessment of Locomotive Performance

By W. A. TUPLIN, D.Sc., M.I.Mech.E.

ALTHOUGH those who develop formulæ for train resistance are usually at pains to warn potential users that in actual practice there are variables (e.g., wind and mechanical condition of vehicles) that may affect matters considerably, one is inevitably tempted to use a formula in order to assess the value of some notable locomotive performance in ordinary service.

The writer has frequently applied the Johansen formula to peak efforts of British locomotives but has more recently been interested in the assessment of mean drawbar horsepower over long runs. The worst deterrent is the arithmetical work, but the reduction of this to a simple routine recorded in tabular form makes it much less formidable.

The work done by the locomotive over any section of line is made up of :—

(1) That done against "resistance," i.e., friction and windage, as estimated, for example, by the Johansen formula.

(2) That corresponding to the change in height of the train above a datum between the beginning and end of the section.

(3) That equal to the change in kinetic energy of the train between the beginning and end of the section.

The sections are chosen so that speed variation in any one is within about 15 per cent of the mean speed. It is assumed that the work done in any section against resistance is adequately estimated by the Johansen formula worked out for the mean speed in that section. The error involved here is an underestimate of the work done to an extent that does not normally exceed 4 per cent and is usually less than 2 per cent.

To deal with (2), the heights of the ends of the section above a datum are required. These are recorded as "static height" S, expressed as a multiple of 14·7ft. The significance of this unusual unit is that the change in static height divided by the number of minutes in which it is effected gives the drawbar horsepower (d.h.p.) per ton of train-weight for (2).

To deal with (3), the speeds of the train at the beginning and end of each section are recorded as "kinetic height" K, expressed as a multiple of 14·7ft by dividing the square of the speed in miles per hour by 442. The "total height" $(S+K)$ at the end of each section is denoted by H.

The drawbar horsepower per ton of train weight required to produce the changes in height and speed in any section is the change in H divided by the number of minutes in which it occurs. The drawbar horsepower so determined covers (2) and (3).

Where a train is braked for a speed restriction or a stop at a particular point, that point is taken as the end of one section and the start of the next. For the beginning of the second section, K corresponds to the speed at the division-point, but for the end of the preceding section, the value taken for K is that corresponding to the speed when the brakes are first applied. This credits the locomotive with having previously given to the train the kinetic energy dissipated by braking. This is unjustifiably favourable to the locomotive only in the rare cases in which it could not have kept the train running to the end of the section at the speed that it had when the brakes were applied.

Table I gives, for speeds from 20 m.p.h. to 99 m.p.h., the horsepower per ton J absorbed in resistance according to the Johansen formula and also the kinetic height K. It is usual to present such information graphically, but the writer finds tables much more convenient for frequently repeated use.

Table II illustrates the application of these methods to the estimation of the drawbar horsepower developed during a run between Leamington and Paddington in 1926. The development of 35 d.h.p. per square foot of grate area for about one and a half hours represents high-grade locomotive performance not uncommon on the Great Western Railway in those days, but not reached anywhere in Great Britain since 1939.

To assess locomotive performance in this way it is necessary to determine the empty weight of the train from the figures displayed on each vehicle and to make an addition to represent the weight of the passengers and luggage. The really meticulous observer would count the passengers so that their weight might be estimated on the basis of (say) fourteen per ton, including luggage, but it is unlikely that anyone has ever done so. An addition of about 5 per cent to the empty weight is a reasonable allowance for a full complement of passengers in a corridor train.

The values of S for the various timing points may be determined from heights above sea-level or, where such figures are not easily obtainable, by calculation from published gradient profiles. Any datum may be used: in Table II the datum height is that of Paddington Station.

The passing times at the selected points are noted and are recorded in the table in minutes and decimals of a minute. The speed of the train in the immediate vicinity of each timing point is determined by stop-watch and mileposts or by the seconds hand of an ordinary watch and rail-lengths. For this purpose there is no need to determine the speed with any high precision; an error of 2 m.p.h. makes no appreciable difference to the final result, nor, in any practical case, to the figures for power output over the sections of line adjacent to the timing point concerned. The speeds so determined are recorded in col. 4 of Table II. Where two figures are given on one line (e.g., for High Wycombe and for Old Oak Junction), the first refers to the speed when brakes were applied and the second to the speed at the timing point.

The average speed figure on each line of column 5 is sixty times the difference in "miles" between that line and the preceding one divided by the corresponding difference in minutes. The value of K in each line is

TABLE I

M.p.h.	J	K	M.p.h.	J	K
20	0·33	0·90	60	1·88	8·1
21	0·34	1·00	61	1·94	8·4
22	0·35	1·10	62	2·00	8·7
23	0·36	1·20	63	2·08	9·0
24	0·38	1·30	64	2·15	9·3
25	0·40	1·40	65	2·22	9·6
26	0·42	1·53	66	2·30	9·9
27	0·44	1·64	67	2·38	10·2
28	0·46	1·78	68	2·45	10·5
29	0·48	1·90	69	2·52	10·8
30	0·5	2·00	70	2·60	11·1
31	0·52	2·15	71	2·68	11·4
32	0·55	2·30	72	2·76	11·7
33	0·57	2·46	73	2·84	12·0
34	0·6	2·60	74	2·92	12·4
35	0·63	2·75	75	3·00	12·7
36	0·66	2·90	76	3·09	13·1
37	0·68	3·10	77	3·18	13·4
38	0·72	3·25	78	3·27	13·7
39	0·77	3·40	79	3·36	14·1
40	0·83	3·6	80	3·45	14·5
41	0·89	3·8	81	3·56	14·9
42	0·95	4·0	82	3·67	15·2
43	1·00	4·2	83	3·78	15·6
44	1·08	4·4	84	3·89	15·9
45	1·12	4·6	85	4·00	16·3
46	1·15	4·8	86	4·12	16·7
47	1·20	5·0	87	4·24	17·2
48	1·25	5·2	88	4·36	17·6
49	1·30	5·4	89	4·48	17·8
50	1·35	5·6	90	4·60	18·3
51	1·39	5·9	91	4·73	18·7
52	1·43	6·1	92	4·86	19·2
53	1·48	6·3	93	5·00	19·6
54	1·53	6·6	94	5·14	20·0
55	1·58	6·8	95	5·28	20·4
56	1·64	7·1	96	5·42	20·8
57	1·70	7·3	97	5·57	21·2
58	1·75	7·6	98	5·71	21·6
59	1·81	7·9	99	5·86	22·1

TABLE II.—*Locomotive, G.W.R., Four-Cylinder, 4–6–0, "Star" Class No. 4042. Laden Weight of Train, 450 Tons*

Timing point	Fixed		Observed		Calculated							
	Miles	S	Minutes T	Speed, m.p.h.	Average m.p.h.	K	$H=S+K$	$\frac{\Delta H}{\Delta T}$	J	$\frac{\text{D.h.p.}}{\text{Ton}}$	D.h.p.	$\frac{\text{D.h.p.}}{\text{Grate}}$
Leamington	0	7·7	0	0	—	0	7·7	—	—	—	—	—
Fenny Compton	11·1	18·3	17·1	47	39	5·0	23·3	0·91	0·77	1·68	760	28
Cropredy	16·2	17·7	22·7	68	54·5	10·4	28·1	0·86	1·55	2·41	1090	40
Banbury	19·8	13·9	25·7	75	72	12·7	26·6	−0·50	2·76	2·26	1020	38
Aynho Junction	24·9	12·0	29·9	68	73	10·4	22·4	−1·00	2·84	1·84	830	31
Ardley	30·1	17·7	35·0	57	61	7·3	25·0	0·51	1·94	2·45	1100	40
Blackthorn	36·9	8·3	40·4	83	75·5	15·6	23·9	−0·20	3·04	2·84	1280	47
Ashendon Junction	43·2	10·5	45·6	65	71·5	9·5	20·0	−0·75	2·72	1·97	880	32·5
Saunderton	55·8	20·4	57·9	48	62	5·2	25·6	0·45	2·0	2·45	1100	41
High Wycombe	60·7	12·6	62·7	65/40	61	9·5/3·6	22·1/16·2	−0·67	1·94	1·27	570	21
Beaconsfield	65·6	15·3	67·8	56	58	7·1	22·4	1·21	1·75	2·96	1330	49
Greenford	79·5	2·2	79·1	73	74	12·0	14·2	−0·72	2·92	2·20	1000	37
Park Royal	82·7	2·2	81·6	66	77	9·8	12·0	−0·88	3·18	2·30	1030	38
Old Oak Junction	84·0	0·8	83·0	65/35	56	9·5/2·75	10·3/3·6	−1·21	1·65	0·44	200	7
Paddington	87·3	0	88·0	50/0	40	5·6/0	5·6	0·4	0·83	1·23	550	20
										Average Leamington to Park Royal	980	36
										Average Leamington to Paddington	950	35

determined from Table I for the speed recorded in the fourth column on that line. Each figure in column 7 is the sum of the corresponding figures in columns 2 and 6. Each figure in column 8 is the quotient of the change in H and the change in T between that line and the preceding one. Where there are two H-figures on one line, the first is associated with the preceding line in determining ΔH and the second with the succeeding line. Each value of J is determined from Table I for the speed recorded on the same line in column 5. Each figure for d.h.p./ton is the sum of the two preceding figures on the same line. The drawbar horsepower is determined by multiplying the d.h.p./ton by the weight of the train and finally the drawbar horsepower per square foot of grate is determined by division. The average drawbar horsepower over any consecutive series of sections is determined by summing the products of drawbar horsepower and time for all the sections concerned and dividing by the total time.

Slide-rule working in conjunction with the tabular lay-out enables the calculations in Table II to be effected in less than an hour.

A somewhat surprising feature of the run represented in Table II is that nearly the highest power output occurred on a downhill stretch. This is unusual on British main lines, but was probably common on the Paddington–Birmingham route in the 1920s because the schedules left no time for easy running, but, on the other hand, demanded the best possible effort from the engine, both up and down the relatively short banks. The adjective "short" is used because, for example, even at 83 m.p.h. the train was still accelerating at the foot of the 1 in 200 bank between Ardley and Blackthorn.

There is good reason to suggest that a criterion of excellence of locomotive performance in power output in relation to size is the drawbar horsepower per square foot of grate for some specified period. It is quite remarkable how the peak efforts of a variety of British locomotives work out at about 50 d.h.p. per square foot for periods up to about four minutes. As an average over four hours or more, 30 d.h.p. per square foot represents first-class work, and 36 is the corresponding figure for an hour. For periods from one to four hours a "high-class power output" in drawbar horsepower per square foot may be expressed as $38-2\times$ (duration in hours).

The foregoing figures are derived from examination of records of a number of unusually good performances by many classes of locomotive over different roads. Not all British express passenger locomotives have proved themselves capable of attaining this general standard, but the best of the older ones have certainly done so. During the special test run from Crewe to Glasgow with a 600-ton train in 1939 the L.M.S. "Pacific" No. 6234, fitted with a double blast pipe, averaged about 33 d.h.p. per square foot for 2 h 10 min from Winsford to Carlisle. In ordinary service a Great Western "King" has maintained the same average for 2¾ hours between Paddington and Exeter, but this was more than the schedule demanded with the normal load and was therefore exceptional. The 157 min timing of the L.N.E.R. "Coronation" with 325 tons from King's Cross to York is estimated to have demanded an average drawbar horsepower of about 1300, or about 32 per square foot of grate with the A4 "Pacifics," which seem to have found it a shade too tight as the first stage of an everyday task lasting for six hours. Southern "School" class 4-4-0s have developed about 1000 d.h.p., or 35 per square foot of grate for about 1½ hours in taking trains of 520 tons from Waterloo to Southampton.

The fact that on four different railways four different classes of locomotive with grate areas from 28 to 50 square feet show best performances closely approximating to the formula quoted above is good evidence that this criterion of performance is a sound one. It may not become universally popular, as it shows some highly acclaimed efforts to be little more than mediocre, but it does afford a common basis of comparison on which a locomotive performance may be appraised by a single number, easily comparable with a standard figure for the duration concerned.

Whilst there is room for discussion as to the exact nature of the criterion, it may at least be said that some method of assessing performance is necessary if train timing is to have any useful purpose at all. The presentation of a table of times and speeds is meaningless to anyone who is not in a position to compare them with records of other runs on the same route, and its only commendation is that it is an effortless task for the author. Even those readers who are familiar with normal running over various routes may easily form incorrect impressions of the relative values of performances on different runs unless a rational criterion is applied to them. This necessarily involves some calculation and that, it would seem, is more appropriately carried out by the author than the reader of any article that purports to expound locomotive performance.

Iron and Steel Institute in Austria

No. III—(*Continued from page 437, October 5th*)

A Lead Works

IF he has experience of operations similar in nature to those that he is called upon to observe, even though no more than a little command of a foreign language, the English-speaking engineer abroad can count upon learning profitably enough what is happening in a foreign engineering works. But when prior technical knowledge of the processes concerned is lacking the bar of language becomes more effective. Observation of what is going on, which can elsewhere illuminate an otherwise ill-understood explanation, here fails. Nor can the guide, however well-intentioned and patient, be expected to explain even the elementary without using technical terms strange to the guided. Such was the situation of this writer on the morning of September 15th, when a visit was paid to the lead works of the Bleiberger Bergwerks Union at Gailitz (Fig. 8). An account of this works must then be short, lest from some error of understanding it proves also inaccurate.

The ore treated at this works carries about 4·5 per cent each of lead and zinc, principally in the form of sulphides, closely intermixed. The two minerals are separated by froth flotation. The lead concentrates are roasted in Dwight-Lloyd continuous furnaces, whereby most of the lead is reduced to the metallic state. The remainder of the lead is recovered in a lead blast-furnace. Zinc ore is similarly roasted and thereby sulphuric acid is produced. The roasted ore is partly converted into lithopone, a base material for dyestuffs containing 30 per cent of zinc sulphide and 70 per cent of barium sulphate, and partly into zinc sulphate. Molybdenum, present in the ore as lead molybdate, is also recovered.

Much extension and rebuilding is going on in the works and in particular a very fine new chemical plant producing a wide variety of compounds of lead, zinc and barium is now in operation.

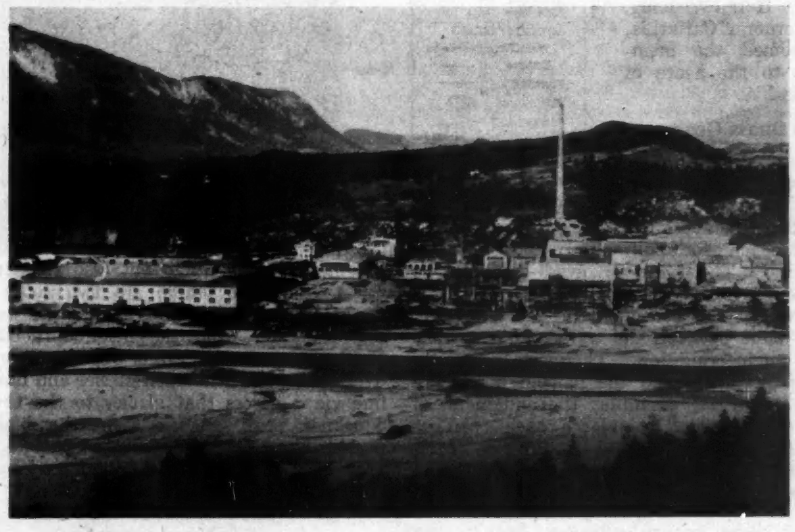


FIG. 8—BLEIBERGER BERGWERKS-UNION CHEMICAL WORKS, GAILITZ-ARNOLDSTEIN

Another party on this Saturday visited the Oesterreichisch-Amerikanische Magnesit A.G., at Radenthein. Both parties joined for lunch at Radenthein, given by that firm. After lunch a number of members of the Iron and Steel Institute left the meeting to entrain for Venice, where they joined the Institute of Metals. The remainder of the members had the afternoon free at Portschach and later enjoyed a dinner and dance at the hotel Werzer-Astoria. At the dinner Mr. Mather took the opportunity to thank the Austrian hosts on behalf of the members of the Institute. He remarked that the value of the meeting lay as much in the opportunity it had afforded members of

meeting Austrians as in seeing Austrian industry. In particular he expressed thanks to Professor Walzell and to Colonel Watson, the joint honorary secretaries of the Austrian Reception Committee, for their work in connection with the meeting. Lastly, he proposed the toast of the Eisenhutte Oestreich, associating with it the name of Dr. Oberregger and the Austrian Iron and Steel Industry. In reply, Dr. Oberregger said that it had been a pleasure to receive the members of the Iron and Steel Institute and to show to them the beauties of the country and its industrial development. He sincerely hoped it would not be long before they came back again either privately or officially.

Professor Platzer then presented Mr. Mather with an old photograph of the first visit of the Iron and Steel Institute to Austria. It dated back to 1907. Finally, Herr Wedenig, Governor of Carinthia, welcomed the members to the State of Carinthia.

The Gross-Glockner Pass

On Sunday, September 16th, four coach-loads of members left Portschach for Zell-am-See. The route involved crossing the Gross-Glockner pass. This road, which is shown on the accompanying map, Fig. 9, was built between the wars and is a very fine engineering job. There are no really steep gradients and the hairpin bends are so open that, assuming the judgment of the driver is good, even large coaches can get round without the need to reverse. It is apparent that the road was built not only to give access from north to south across the main Alpine range but also to attract the tourist. For there are two spurs off the main road. Coming from the south one leads off from the neighbourhood of Heiligenblut to the Franz Josefhaus hotel, overlooking the Pasterzen glacier and having fine views across that glacier to the Gross-Glockner peak, 3797m high, the highest peak in Austria. It ends in a spacious car park at a level of about 2400m and has a length, as the crow flies (not as the road twists), of about 5km. The other, rather more than 1km long, climbs from the main road to an hotel at the top of the Edelweiss Spitze, at 2577m, with the object of providing a fine panoramic view of glacier-clad mountains towards the Fuscherkarkopf, 3332m, and the Gross-Glockner group beyond. The Gross-Glockner pass is not a very high one. But the road remains more consistently at a high level than it does on most other mountain passes. The top of the main road reaches a level just above 2500m. But the road remains at a level exceeding 2200m for a distance of 5km or 6km as the crow flies.

On the particular occasion of the Iron and Steel Institute visit, the programme called for a stop for lunch at the Franz Josefhaus. Unfortunately, there were delays on the way. In particular one of the coaches broke down shortly before reaching the pass. Luckily, it proved possible to accommodate all members on the remaining three. But the Franz Josefhaus was not reached until mid-afternoon. Owing to deterioration of the weather, hitherto sunny, the Gross-Glockner and its accompanying peaks were wrapped in cloud, although the glacier itself and a snow-peak at its upper end were clear. It was an omen promising ill for the remainder of the journey across the pass. For when lunch was finished daylight was beginning to fail and by the time the tunnel at the top of the pass was reached the clouds were down and daylight gone. The run from that tunnel to a point a couple of kilometres beyond the Edelweiss spurs had to be completed in darkness and thick mist. It is a tribute to the engineers who laid out and built the road so finely, as well as to the skill of the coach drivers, that the trip was completed in safety and without incident.

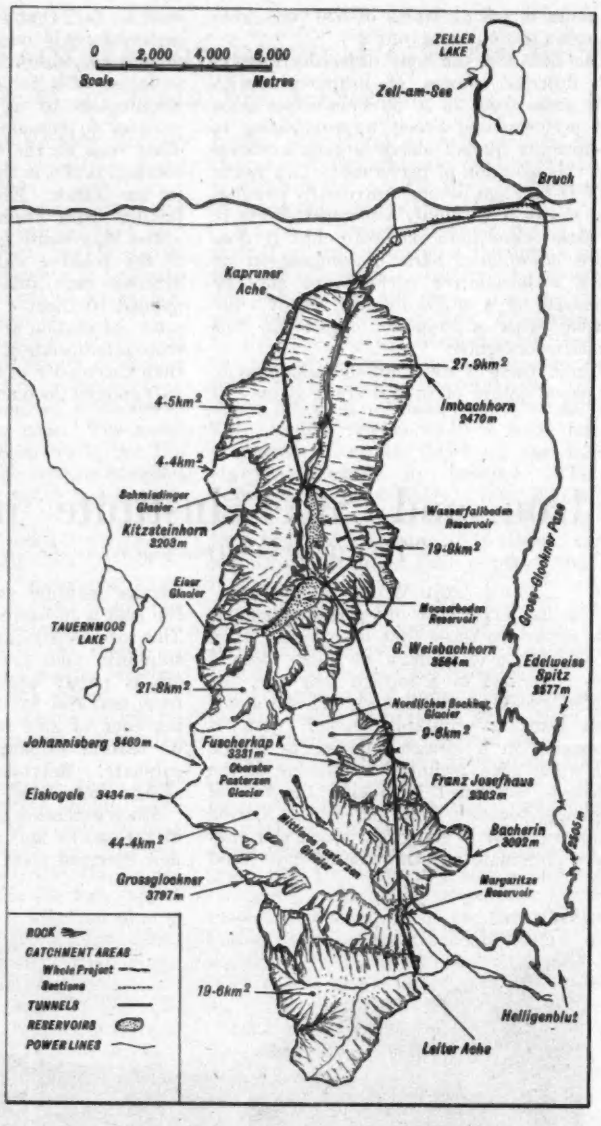


FIG. 9—MAP OF KAPRUN POWER PROJECT AND GROSS-GLOCKNER PASS

Glockner-Kaprun Hydro-Electric Scheme

The next day, under heavy clouds and frequent rain, a small party of members went out to see the Glockner-Kaprun hydro-electric works, now being carried out by the Tauernkraftwerke A.G. The map, Fig. 9, shows the situation of these works, which are designed to develop the power potentialities of the Kapruner Ache and the glacier mass to its southward. The Limberg dam, whose construction is now nearly complete, is creating the Wasserfallboden reservoir, with a top water level of 1672m. From this reservoir a pressure tunnel 8·9km long carries the water to headworks and a surge shaft above the Kaprun power station, whose tail water level is at 781m. The waters of a number of side-streams, under which the tunnel passes, have been diverted

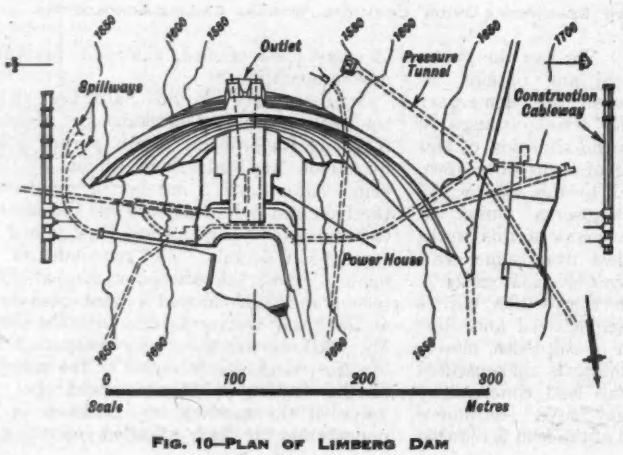


FIG. 10—PLAN OF LIMBERG DAM

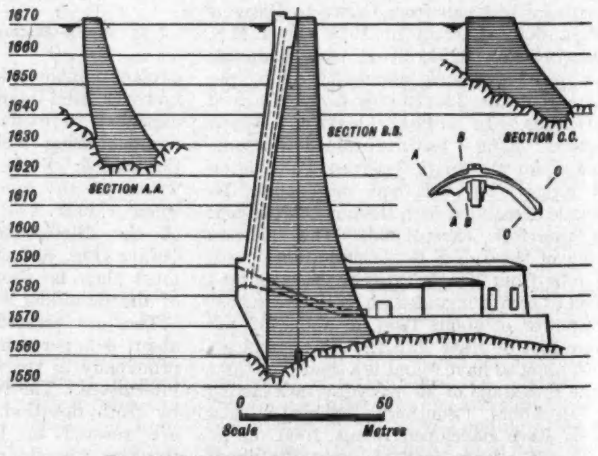


FIG. 11—SECTIONS THROUGH LIMBERG DAM

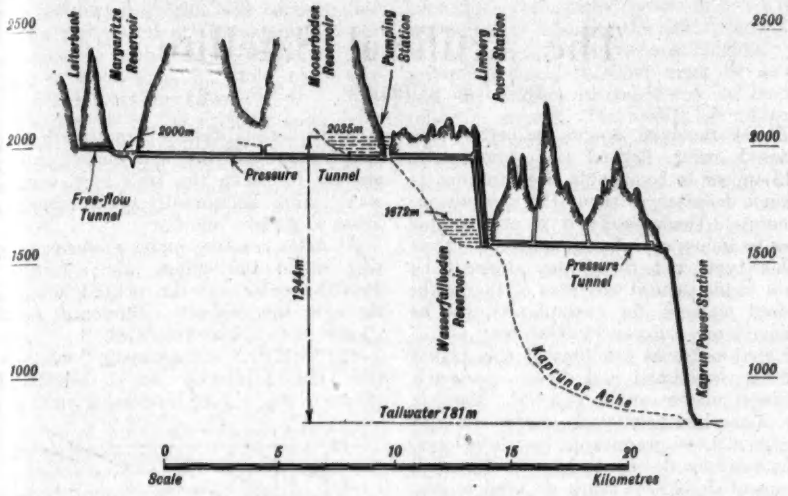


FIG. 12—PROFILE OF KAPRUN PROJECT

FIG. 13—LIMBERG DAM

FIG. 14—WASSERFALLBODEN RESERVOIR

into it. Upstream of the Wasserfallboden two more dams, now under construction, will create the Mooserboden reservoir, with a top water level at 2035m. Thence a pressure tunnel is being driven to a point on the mountain above the Limberg dam, on the downstream side of which there remains to be built a power station. The capacity of these two reservoirs is much more than sufficient to store all the water from their watersheds. Work is therefore being undertaken to collect also the whole flow of water from the Pasterzen glacier below the Gross-Glockner. A small reservoir, the Margaritze, is to be created here at a level of 2000m and water from it will flow through a tunnel 12km long to the Mooserboden reservoir. In addition, inlet works are to be constructed on the Leiter Ache 2km further south and its waters diverted through a free-flow tunnel into the Margaritze reservoir. The map shows the extent of the works and the areas of the various catchments; and the diagram, Fig. 12, the levels of the various reservoirs. The respective storage capacities are Wasserfallboden, 80 million cubic metres; Mooserboden, 68 million cubic metres, and Margaritze, 1 million cubic metres. The tunnel from the Margaritze reservoir to Mooserboden is designed to carry some 17 cubic metres per second and that from the Wasserfallboden to the headworks above the Kaprun power station for a flow of about 32 cubic metres per second. The power station at Kaprun will be equipped to generate 200MW and that at the Limberg dam for 100MW.

We do not intend here to give at all a full description of these works. That can await the completion of the scheme. Some points of interest are, however, worthy of special notice. First, it will have been observed that the water level in the Margaritze reservoir is lower than that in the Mooserboden. There will be a pumping station near the Mooserboden dams which will lift the water into that reservoir. It will also be noticed that the machinery in the power house at the Limberg dam will be below the level in that reservoir. The Francis turbines here will operate under back pressure and discharge into the reservoir, a provision that permits the best use to be made of the water whenever the level in the reservoir has been drawn down. Furthermore, in this station the two generators are to be coupled to pumps as well as to the turbines. At times of low loading water will be pumped back from this reservoir to the Mooserboden above. In the picture of the Limberg dam under construction, reproduced in Fig. 13, the two pipes through the dam that will be connected with the machinery in the station can be seen, placed centrally in the arch dam. In another view of the dam under construction, Fig. 14, the construction cables can be seen. The drawings, Figs. 10 and 11, show the design of the dam.

In constructing the works the Tauernkraftwerke A.G. has had to make provision for carrying the work forward during the winter, when surface means of access to sites at such high levels will be impeded by snow. A railway links the main storage area near the Kaprun power station with the Austrian railway system. From that area there is an overhead ropeway to the Limberg dam. In addition there is another means of access. From a point in the Kapruner valley, about 3km below the dam and at a level of only about 1000m, a tunnel has been driven into the mountain. It is level for about one-third of its length at the lower end. Thence, within the moun-

tain, a cable railway runs up at about 45 deg. to meet a final section of level tunnel, which emerges near the base of the dam. It was by this route that the members of the Iron and Steel Institute were carried up to the dam. This tunnel, besides giving access for workers to the site, was originally intended to carry down high-tension cables from the Limberg power station to link with a 110kV line carrying the power to the switchgear at Kaprun. However, it appears that certain difficulties have since emerged. There is a drop in level of some thousands of feet and doubt is felt whether a pressure-filled oil cable, or a gas-filled cable, could be satisfactorily designed to meet these conditions.

On the day of the Iron and Steel Institute visit, as we have already mentioned, the weather was bad. Indeed, upon their arrival at the downstream side of the Limberg dam cloud was so far down that it was only barely possible to see, through the mist, the line of the dam crest. However, defying the weather, the party walked up the mountainside to reach crest level and to observe the work going forward upon the final completion of the dam. According to programme, the party should next have moved up to the site of the Mooserboden works. But the weather scored a victory. A telephone message revealed that that site, too, was wrapped in cloud. The visit was cancelled and the members moved down the mountain by the route they had ascended and took an unexpectedly early lunch at the small but charming Kesselfall hotel in the Kapruner valley, afterwards viewing the remarkable double waterfall from which the hotel takes its name.

The coaches then carried the party to the Kaprun power station. Here there are already installed two 45,000kW machines, each consisting of a 50,000kVA alternator and two Pelton wheels, running at 500 r.p.m. on a horizontal shaft. There are to be two more machines, each consisting of a 55,000kW alternator and two Pelton wheels on a horizontal shaft and also running at 500 r.p.m. One of these latter machines, at the time of the visit, was running under test. The installation of the other remained to be completed. Current is generated at 10kV and transformed for transmission to 110kV. In this station we noticed a Pelton wheel for one of the larger machines whose cups were cast solid with the main disc instead of being bolted to it as is more usual. The makers are Escher Wyss, of Switzerland.

Lastly we were given the opportunity to see a model of the Limberg dam, constructed to scale and designed to serve the needs of research. The model has been built of Kieselguhr and gypsum in a mixture providing a modulus of rigidity one-tenth that of concrete. The "water" load is applied from steel beams whose feet are imbedded in concrete through a large number of screw jacks acting through coil springs. The load applied is measured by the deflection of the springs. On the downstream side of the model a number of clock gauges are used for measuring deflections of the dam structure, and strain gauges are in use for measuring strains at various parts of the surface of the dam. Great interest was taken in this model by the Iron and Steel party, many of whose members had not before seen an example of such a model.

In the evening there was an informal dinner at the Hotel Pinzgauerhof in Zell-am-See, at which "goodbyes" were spoken. The following day the Iron and Steel Institute members entrained for the return journey to England. For ourselves we went to Salzburg, returning thence by air.

The Artificial Satellite

By ERIC BURGESS, F.R.A.S.

A BODY revolving round the earth in a closed orbit beyond the atmosphere would appear to be capable of continuing its motion indefinitely without the expenditure of energy. Theoretically it is possible for bodies to follow an infinite number of orbits of this type and there may, indeed, be several small natural satellites of the earth, captured meteors, for example, as well as the huge moon. Recently it has been postulated that artificial satellites of this planet could be established and diverse proposals have been put forward to this end. Many of these have been extremely ambitious and verging on the impracticable, but there have, on the other hand, been suggestions for small instrumented vehicles which do need serious consideration.

There appears to be no doubt about the uses of the artificial satellite for the extension of the high-altitude research programme at present being undertaken with large rockets. Further work could be done on cosmic radiation, ionospheric radio transmission, solar spectra into the extreme ultra-violet, terrestrial spectra and albedo and other astronomical problems. Before one can decide whether or not such schemes are fanciful it is necessary to examine the fundamental theory of the satellite vehicle and then discuss the engineering problems involved.

The simplest case of an orbiting body is the one in which the path is circular. The velocity needed to maintain the orbit can be calculated by equating the gravitational force at the radius of the orbit to the centrifugal force, namely :—

$$V = \sqrt{g_o \cdot R^2/r},$$

where g_o is the acceleration of gravity at the surface of the earth, R is the radius of the earth and r is the radius of the circular orbit. The period of a body moving in such an orbit is readily obtained from :—

$$T = \frac{2 \cdot \pi}{R}\sqrt{\frac{r^3}{g_o}},$$

and it will, of course, be advantageous to have this some fraction of the period of rotation of the earth for tracking purposes.

One interesting orbit is possible at which the period is twenty-four hours, so that the orbiting body would appear to be stationary with respect to an observer of earth. Such an orbit would have obvious advantages for establishing a radio or television repeater.

The total energy of a body in the orbit is given by the sum of the potential and kinetic energies ; that is

$$E = \frac{g_o \cdot R}{2r}(2r - R).$$

A body revolving at the limits of the atmosphere, about 200 miles (322km) would thus have an energy of $3 \cdot 3 \times 10^7$kg.m/kg, whereas one in the twenty-four hours' orbit would have an energy of $5 \cdot 8 \times 10^7$kg.m/kg.

A simple analysis will show that it is not possible to shoot a missile from the surface of the earth into a closed orbit. All such missiles must follow paths which cut the surface of the earth at two points, at take-off and impact. In order to establish the circulating body it is necessary to apply a propulsive force at two stages.

It is found that the most economical entry orbit is the portion of an ellipse which grazes the surface of the earth at perigee and touches the circular orbit at apogee. A rocket missile must apply its motors to produce acceleration in two stages :—

(*a*) In vertical take-off from earth to pass swiftly through the atmosphere, allowing gravity to curve the trajectory, and then accelerating horizontally with minimum g losses to perigee velocity.

(*b*) After coasting under momentum halfway round the ellipse and reaching the desired circular orbit the rocket is accelerated through the velocity difference between apogee and circular velocities.

The total or "characteristic" velocity for this kind of mission can be calculated as shown in Fig. 1. An interesting point arises,

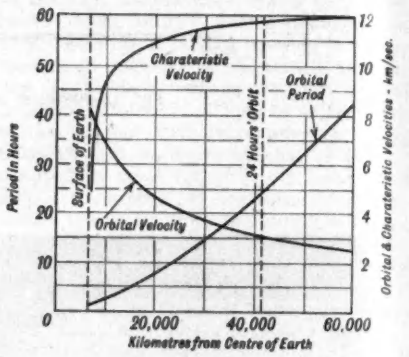


FIG. 1

in that although the energy of the orbital body is never greater than the potential energy of a similar body at infinity, the characteristic velocity needed to establish the orbit can often be greater than the parabolic velocity of escape from the gravitational field of the earth. This results from the two periods of power which necessitate lifting fuel through the gravitational potential.

The closest orbits, just beyond the atmosphere, need a characteristic velocity of nearly 10km per second, which should be compared with the 2·5km per second attained by a modern rocket, such as the two-step combination of German V2 and American WAC Corporal. As will be shown later, it appears quite feasible that the necessary increase in characteristic velocity can be made, thus enabling the orbital body to be placed in position.

When the artificial satellite is moving in its orbit it will be perturbed in its motion, as are the other heavenly bodies. The chief cause of the perturbation will be the equatorial bulge of the earth, the next results from the sun, then the moon and the other planets. The bulge of the earth can affect the motion of the satellite in two ways. If the orbit is circular and in the equatorial plane the displacement will be negligible, theoretically zero. An elliptical orbit in this plane would, however, undergo a rotation of the apsides, so that the geocentric longitudes of the apogee and perigee would advance. In the case of orbits inclined to the plane of the equator there is not only this direct motion of the apsides, but also a regression of the nodes of the orbit. The period of this regression can be calculated and it is fairly short in the case of close orbits (Fig. 2).

The sun's action takes place when the orbit plane differs from the plane of the ecliptic, producing similar effects as the earth's bulge, but of a much longer period, 500 years in the case of the twenty-four hours' orbit and very much more for the closer orbits. The effect of the moon and the

planets on the close orbit will be negligible providing the period of the satellite is not commensurable with that of the moon, the planets, of course, having only extremely small and unimportant effects.

Establishment of the orbiting body in a close orbit will thus minimise perturbations if the orbit lies in the equatorial plane and is circular. In practice it may prove difficult with small, unmanned rockets to create a

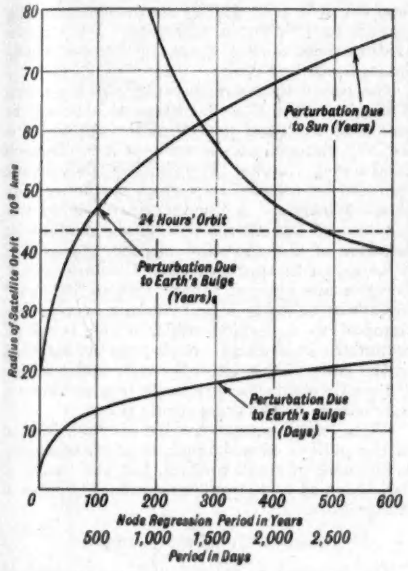

Perturbation Due to Sun (Years)
24 Hours' Orbit
Perturbation Due to Earth's Bulge (Years)
Perturbation Due to Earth's Bulge (Days)
Radius of Satellite Orbit 10⁶ kms
Node Regression Period in Years
Period in Days

FIG. 2

circular orbit and elliptical orbits may result. It may then be found that the direct motion of the perigee and apogee positions in the short period of 50 to 150 days will have to be tolerated. This will not, however, destroy the orbit.

If a simple uninstrumented missile could thus be placed in the circular type orbit and could then be observed from the earth it would prove a useful aid to navigation and could also be used for physical research by radio reflection and observation of its magnitude. The first real use of the artificial satellite may well be in this way.

Two methods of detection are normally considered, by radar and optically. If the

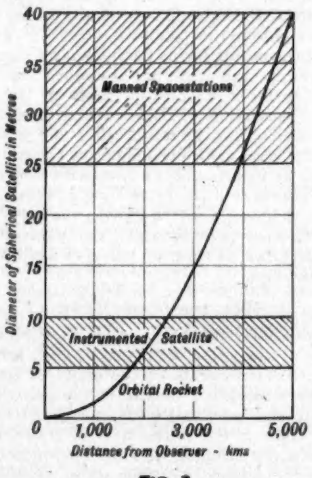


FIG. 3

body is assumed to act merely as a reflector, that is, no transponder is incorporated—the results are still fairly encouraging. A repeater in the missile improves the picture considerably, but cannot be considered for the first tiny satellite. Assuming that the earth station has an aerial array 50 square metres in area and uses a wavelength of 10cm with transmitted power of 2·5 MW, it is possible to calculate the size of the station to be detectable at various heights. The minimum signal received must be 10^{-12}W and the station is considered as being a reflecting sphere. The results are plotted in Fig. 3, together with indications of the probable size of typical orbiting vessels, namely, orbital missile, 1m to 5m; instrumented satellite, 5m to 10m; manned space station, 25m to 100m; and it is apparent that even large stations cannot be detected unless they are in close orbits or have repeaters.

Optical conditions are likewise not too favourable. If it is assumed that the albedo of the satellite is 0·4 it is possible to calculate the visual stellar magnitude for spheres of different radii as in Fig. 4. The result shows that the close orbit satellite cannot be seen with the naked eye, but should be visible in moderate telescopes if its visible surface approximates to a sphere of radius 3m or 4m. Of possible future interest is the fact that a large space station of 100m diameter would be visible to the naked eye as far out as the twenty-four hours' orbit.

It appears then that the concept of an artificial satellite is quite sound, but the question now arises whether or not it is a possible engineering project without assuming atomic reactors, impossible structures, or new super-chemical fuels.

A preliminary analysis would indicate that a three-step rocket would be needed to attain

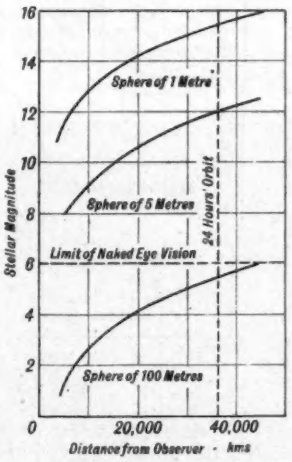


FIG. 4

the required characteristic velocity for the establishment of a satellite in the close orbit. The final velocity of a rocket follows the exponential law

$$V = v \log_e R,$$

where v is the jet velocity and R is the mass ratio, defined as the ratio between initial and final mass after all-burnt.

The German V2 rocket had a mass ratio of 3·4, which could have been increased to 4·5 if propellants had been substituted for the warhead pay load. It is quite possible by using the best materials (uninhibited by wartime scarcities) to construct rockets having mass ratios of 4·0 without undue difficulty. A three-step rocket using step mass ratios of this value would need to develop a jet velocity of 2·4km/sec to reach a characteristic velocity of 10km/sec. In order to overcome g losses, air resistance and reduced take-off thrust it will be necessary to aim at a jet velocity of 2·5km/sec. The peripheral speed of the earth would be held as a reserve for course correction in the entry orbit.

In rocket engineering it is more usual to speak of the specific impulse than the jet velocity, where

$$S.I. = v/g \text{ secs.}$$

For the close orbit satellite we thus need a specific impulse of about 250 seconds if the mission is to be possible.

Many propellant combinations exist which can produce a theoretical specific impulse greater than 250 seconds, but practical motors have so far only operated at about 200 seconds. Some mixtures should yield 300 to 350 seconds, but these are untried. Examples are fluorine and the boron hydrides but such high-energy propellants are not needed for the simple rocket satellite. The table indicates some propellant combinations which might be used to give the required impulse at the present day.

Characteristics of Propellants

Oxidiser	Fuel	S.I.	T. °C.	Density impulse
Liquid oxygen	Hydrazine...	260	2800	272
	Ammonia	250	2750	250
	Aniline	230	3250	250
Red fuming nitric acid...	Hydrazine...	245	—	310
	Aniline	230	2800	272
Hydrogen peroxide	Hydrazine...	250	2400	303
	Aniline	210	2350	260

Propellants are rated by a density impulse in addition to the specific impulse. The density must be taken into account, of course, because it controls the mass ratio which can be obtained. Although a fuel such as liquid hydrogen and liquid oxygen may have a high specific impulse, the density can be such that the adverse effects on the mass ratio will result in a lower characteristic velocity than by using a propellant combination of less energy but greater density. In this connection it is of interest to note that nitric acid is the best oxidiser as far as density is concerned.

There seems to be no doubt that by using modern efficient injectors to ensure maximum combustion efficiency, together with transpiration cooling to take advantage of the highest combustion temperatures, a specific impulse of 250 seconds could be obtained.* Moreover, the propellant combination chosen could have a suitable density impulse for a mass ratio of 4 to be practical. The usual propellant determinants for military use, such as toxicity, ease of handling, commercial availability, storage, cost, &c., would not be of importance for the research vehicle.

Finally, we should consider the payload of the artificial satellite. The design requirements so far laid down indicate that there will be required 1000 lb of take-off mass for each pound of pay load placed into the orbit. This is assuming a pay load factor of 0·1; the V2 was 0·08 and the Viking 0·17. If we are a little more ambitious and instead of the simple missile we aim at a pay load of telemetering instruments and power supplies weighing 200 lb, the build-up of the orbital rocket would be in the following pattern:—The missile would be comparable in size and weight with the projected German A-9/A-10 transatlantic rocket. It would not be neces-

* Recent static tests have indeed produced such figures.

sary to develop a new large motor for the first step, for four motors of the V2 type, giving a total thrust of 104 tons, together with a ring of cellular jettisonable boosters,

	First step	Second step	Third step
	Tons	Pounds	Pounds
Pay load	8·94	2,000	200
Structure	13·4	3,000	300
Fuel	67·02	15,000	1,500
Total	89·36	20,000	2,000

would suffice to power the step. No unusual structural problems would be presented and pumps capable of delivering the requisite amount of propellants have already been constructed. The second and third steps would be very much the same as rockets already in use to-day. The only really difficult part of the project may be the instrumentation for the orientation and rocket firing at apogee, but recent research in the control of guided missiles indicates possible solutions.

The conclusion to be drawn is that, while many ambitious schemes for manned stations and laboratories in space may have to remain on paper for fifty or a hundred years, the small instrumented orbital rocket only needs sufficient financial backing for its establishment. No new engineering techniques are needed and the rocket motors are already available. It would appear that the orbital rocket may be a project which engineers may soon be called upon to pursue following the theoretical work now being undertaken in the military establishments of the United States and elsewhere.

The Design Characteristics of Cross Spring Pivots*

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Introduction

THE most common type of cross spring pivot consists of two pairs of crossed steel strips, of uniform length, width and thickness, which are fixed rigidly at their ends to the two parts between which relative movement is required. A typical example is shown in Fig. 1. Such cross spring pivots have many advantages over pivots embodying plain bearings in the design of engineers' measuring instruments, the externally applied loads being, in general, insufficiently large to cause failure by buckling of the strips or to cause the cross spring pivot to become unstable. The main advantages are that the cross spring pivots are frictionless and, therefore, have no hysteresis effect, are not subject to wear and require no lubrication. These pivots are not always suitable, however, for large angles of rotation because of the shift of the axis of rotation at these large angles. This latter disadvantage is of minor importance in measuring instruments, where the angles of rotation are small and rarely exceed 15 deg. of arc.

Theoretical investigations of the design characteristics of the cross spring pivot, i.e., the relationship between the geometric dimensions of the pivot and its stiffness and the movement of the initial axis of rotation, have been carried out by a number of workers, including Eastman,[1], Wittrick[2] and Haringx.[3] In general, these investigations are complex mathematically and little practical work seems to have been done to check their results.

A practical investigation by Young[4] was concerned with spring strips having a functional length l (see Fig. 1) exceeding 1in,† and was therefore not necessarily applicable to instrument practice where the functional length of the spring strips is usually less than ¼in.

The present investigation was carried out in order to provide information of use to designers wishing to incorporate cross spring pivots in their instruments, and therefore the sizes used were kept within the range usually employed for this purpose.

The work described relates to the type of cross spring pivot most commonly used in which the cross strips intersect at 90 deg. at the mid point of their functional lengths (Fig. 1), i.e., to the 90 deg. symmetrical cross spring pivot. To a lesser degree asymmetrical cross spring pivots are also used, and it is intended to extend the work to this type.

As a first approach to the problem the effect of pure torque on cross spring pivots has been investigated. The effect of externally applied loads on the characteristics of cross spring pivots is being investigated at present, but this aspect is not dealt with in this paper.

* Communicated by the National Physical Laboratory.

† 1in = 25·4mm.

Apparatus Used

An adjustable cross spring pivot was designed to take different lengths and thicknesses of steel strip, and this is shown in diagrammatic form in Fig. 2. It consists of a fixed part C to which is attached a movable part D by means of two pairs of spring strips. The movable part D is made of aluminium alloy in order to reduce to a minimum the effect of its weight

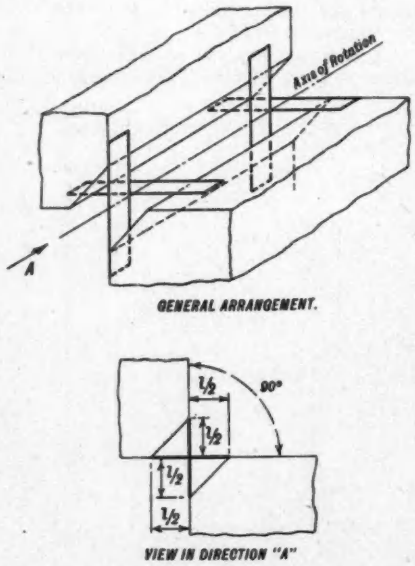


FIG. 1—*Example of 90 deg. Symmetrical Cross Spring Pivot*

on the system, and carries on its upper face a glass graticule E having an inscribed cross line. This graticule is adjustable in two directions at right angles, by means of the set screws F, and the cross line can therefore be accurately aligned with the intersection of the neutral axes of the spring strips. The central portion G of the movable part D is cylindrical in form, and the couple is applied by two equal and opposite loads as shown.

The ends of the spring strips are held in position by the arrangement shown in Fig. 2 (c), consisting of clamping pieces and two set screws passing through clearance holes in the strip. This arrangement permits the use of packing strip of a suitable thickness to ensure that the neutral axes of the spring strips always intersect on the longitudinal axis of the cylindrical part G by means of which the torque is applied. The clearance holes in the spring strips were either punched or drilled, the strip in the latter case being held between two pieces of metal plate and a hole drilled through the sandwich so formed; this prevented any distortion of the spring strip.

The clamping pieces slide in tee slots so that spring strips having functional lengths up to ¾in may be used. The apparatus as constructed will take spring strips of ¼in width and up to 0·020in in thickness. With minor modifications spring strips of greater thicknesses could be tested.

The complete arrangement of the apparatus is illustrated in Fig. 3. From this it will be seen that the fixed part C of the apparatus is securely clamped to the table of a toolmaker's microscope, having co-ordinate movements operated by micrometers which can be read to about 0·0001in. A goniometric scale in the eyepiece of the microscope allows readings of rotation of the crossline on the graticule E to be taken to approximately 1 minute of arc. Torques are applied to the system by nylon threads attached to G and running over pulleys clamped to a wooden table, which is placed around the instrument. Scale pans are attached to the ends of the nylon threads, and addition of equal weights to each scale pan produces a pure torque on the cross spring pivot.

When experiments were first started, friction in the pulleys caused much trouble, especially in the case of small torques, but the fitting of ball bearings to the pulleys eliminated most of this trouble.

Setting Up the Apparatus

The accuracy of setting of the two pairs of spring strips, prior to clamping in position, is of great importance. Any tendency to twist the spring strips during clamping will materially affect the characteristics of the pivot and may also cause the spring strips to buckle. The lengths of the spring strips between the clamping pieces should be equal and the intersection of the neutral axes of each pair of spring strips should lie on a common axis of rotation halfway along their lengths (for symmetrical cross spring pivots). The required accuracy of setting was achieved by the use of two setting jigs, one of which is illustrated in Fig. 4. By assembling the jigs with the upper and lower parts of the cross spring pivot, the fixed part C and the movable part D (Fig. 2) are held rigidly in alignment with each other. Each spring strip is then set in its correct position to an accuracy of 0·001in by inserting slip gauges between the body of the apparatus and the end face of the appropriate clamp; the latter is then tightened in position.

After the spring strips have been set correctly in position, the jigs are removed and the apparatus mounted on the table of the toolmaker's microscope. By focussing on the four spring strips in turn and using the graticule adjusting screws, the crossline on the graticule E (Fig. 2) is brought in line with the initial axis of rotation of the cross spring pivot. This, in turn, is brought into line with the cross wires in the microscope eyepiece. Any movement of the initial axis of rotation can now be observed and measured.

Measurements Made

A series of torques was applied to the movable part D of the cross strip pivot, and, for each torque, measurements of the angle of rotation of D were made by means of the goniometric scale in the microscope eyepiece. Also, the lateral shift of the initial axis of rotation was measured, by bringing the crossline on graticule E into coincidence with the cross wires in the microscope eyepiece by means of the co-ordinate movements of the table.

The torques on each size of cross spring pivot were restricted to a maximum of 6 lb-in.‡ It was considered that torques greater than the latter value were unlikely to be used in engineers' measuring instruments, and, in fact, a torque of 6 lb-in was reached only on the

‡ 1 lb-in = 1·1525kg-cm.

shorter lengths of the 0·015in and 0·020in thick spring strip, giving rise to angular rotations of 8 deg. for the 0·158in length of 0·015in spring strip, and angular rotations of 4 deg. and 7 deg. respectively for the 0·158in and 0·410 in lengths of 0·020in spring strip. In the case of the thinnest spring strips rotations of 35 deg. to 45 deg. were obtained. Measurements were then taken with decreases in torque from the maximum value. Two complete sets of readings were taken for each cross spring pivot, the spring strips being dismantled and reassembled between the two sets; this provided information about the effect of slight differences in clamping and setting.

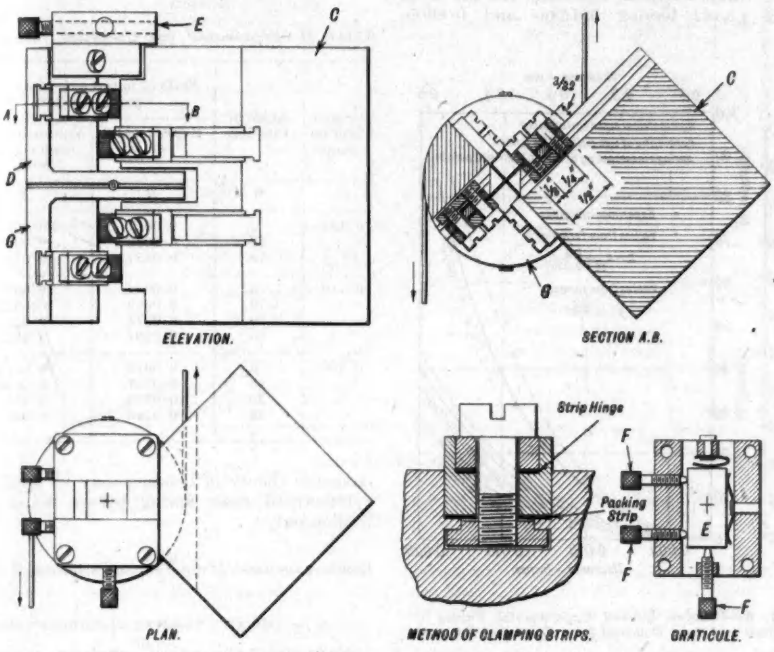


FIG. 2—*Adjustable Cross Spring Pivot*

Altogether, five thicknesses of spring strip were used, of the following nominal sizes:—0·005in, 0·0065in, 0·010in, 0·015in, 0·020in.

In some cases the actual thickness was found to vary by as much as 0·001in from the nominal value, and allowance was made for this departure from nominal size when analysing the results.

Each of these spring strips was made in the three following functional lengths:—0·158in, 0·410in, 0·660in

Correlation and Analysis of Results of Measurements

Relation Between Torque, Angular Rotation and Geometric Size of Cross Spring Pivot.—For any one size of cross spring pivot it was found that the angular rotations produced by the series of progressively increasing torques were very similar to those produced by the same torques progressively decreasing from the maximum value. In other words, the hysteresis effect was negligible, as was to be expected.

The mean values of the angular rotations for each setting were then plotted against the applied couple. As measurements were obtained for two settings for each size of cross spring pivot, two sets of values were plotted on each graph, as shown in Fig. 5. These two sets of values were in such good agreement that no difficulty was experienced in drawing a mean line representing the performance of that size of pivot. This close agreement indicated that the accuracy with which the spring strips could be set in position by the method described above was completely satisfactory.

The graphs of angular rotation plotted against applied couple indicated in every case that the angle of rotation was very nearly proportional to the applied torque. A slight increase in stiffness, i.e., the applied couple per radian deflection, was found in the case of 0·0050in spring strips, at the larger angles of rotation, but this was small enough to be neglected in practice.

From the experimental results the stiffness was calculated for the different combinations of length and thickness of the spring strips and plotted against the spring strip thickness, as shown by the full line curves in Fig. 6.

Movement of Initial Axis of Rotation.—For each of the three lengths of spring strip investigated, a graph of the movement of the initial axis of rotation per inch length of spring strip was plotted against angle of rotation, as shown by the full line curves in Fig. 8. It was found that the actual movement of the initial axis of rotation of any of the cross spring pivots investigated was less than 0·003in for angular rotations up to about 10 deg. For greater angular rotations the movement increased considerably, reaching a value of 0·06in for a 50 deg. rotation of a cross spring pivot 0·66in long and 0·005in thick.

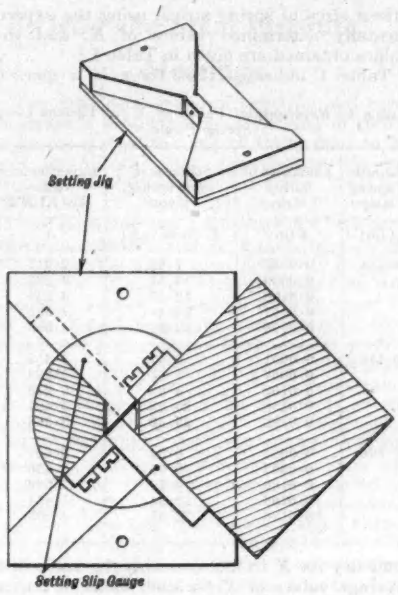


FIG. 4—*Setting Jig Used for Adjusting Cross Spring Pivot*

Determination of Empirical Formula Relating Stiffness and Geometric Size of Cross Spring Pivot

Let

b = width of single strip (in).

d = hickness of strip (in).

I = Moment of inertia of normal section of single strip about its neutral axis = $\frac{bd^3}{12}$ (in^4).

l = length of strip (in).

E' = effective Young's Modulus for the material of the strip taken as $27{\cdot}5\times10^6$ lb/in^2. (The measured values for E range from $27{\cdot}2$ to $29{\cdot}2\times10^6$ lb/in^2.)

K = stiffness of pivot (lb-in/radian).

The theoretical relationship between stiffness K and geometrical dimensions of the strip is of the form

$$K = X \cdot \frac{E'I}{l}, \text{ where } X \text{ is a constant} \quad . \quad . \quad (1)$$

Values of X were calculated for each of the

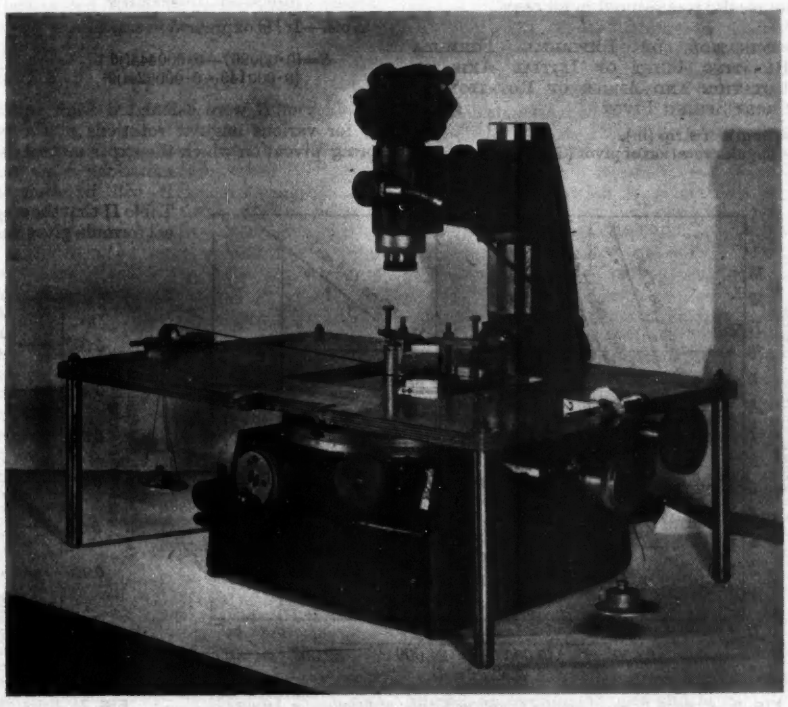


FIG. 3—*Cross Spring-Pivot Mounted on Toolmaker's Microscope*

fifteen sizes of spring strips, using the experimentally determined values of K, and the values obtained are given in Table I:

Table I indicates that there is a general

TABLE I—*Experimental Values of X for Various Cross Spring Pivots*

Length of spring strip	Thickness of spring strip	Stiffness of cross spring pivot	Experimental value, $X=Kl/E'I$
l (in)	d (in)	K (lb-in/rad.)	X
0·158	0·0055	1·92	2·917
	0·0066	3·51	3·086
	0·0100	12·37	3·127
	0·0157	44·47	2·905
	0·0190	82·91	3·056
0·410	0·0051	0·67	3·313
	0·0067	1·51	3·293
	0·0102	5·23	3·233
	0·0158	20·45	3·401
	0·0198	39·50	3·338
0·660	0·0054	0·54	3·621
	0·0067	0·95	3·336
	0·0100	3·39	3·580
	0·0158	12·94	3·464
	0·0188	22·67	3·603

tendency for X to increase with the value of l. Average values of X for each value of l were then calculated and these gave:

l=0·158in X=3·018
l=0·410in X=3·316
l=0·660in X=3·521

Assuming that the increase of X with l was due to a constant uncertainty in the determination of the effective length of l, it was found that when the factor X in formula (1) was replaced by the expression $\frac{4l}{l+0·035}$, the values calculated from the modified formula agreed to within 1·5 per cent with the average experimental values. Substituting for X in formula (1), the following empirical formula was obtained:—

$$K=4\frac{E'I}{(l+0·035)} \quad . \quad . \quad . \quad . \quad (2)$$

Note.—If b, d and l are expressed in cm, and E' in kg/cm², then

$$K(\text{kg-cm/radian})=4\frac{E'I}{(l+0·089)} \quad . \quad . \quad (3)$$

Substituting in equation (2) values of I corresponding to thicknesses of the spring strips intermediate between those actually used, values of K were calculated and plotted on the graph of Fig. 6. It will be seen that close agreement with the curves obtained from the experimental results was secured in all cases.

Determination of Empirical Formula Relating Shift of Initial Axis of Rotation and Angle of Rotation of Cross Spring Pivot

l=length of strip (in).
θ=angular rotation of pivot (degrees).
S=shift of initial axis of rotation (in/in length of spring strip).

It was assumed that the three experimental curves in Fig. 8, giving the relation between the shift of the initial axis of rotation and the angle of rotation for the lengths of spring strip investigated, have equations of the form:

$$S=A\theta+B\theta^2 \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where A and B are constants for the length considered.

The values of these constants for the cross spring pivots having 0·158in and 0·660in

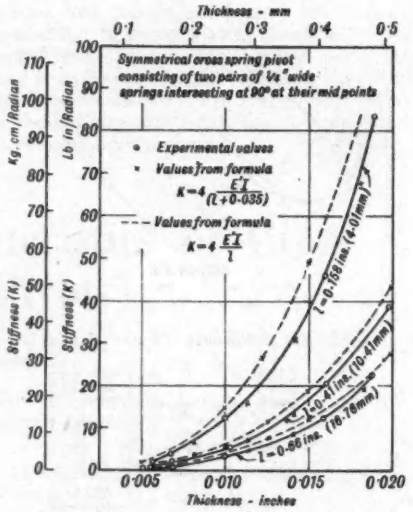


FIG. 6—*Relation between Experimental Values of Stiffness and those Obtained from Empirical Formula*

lengths of strip respectively, were determined in the following manner.

(a) 0·158*in Cross Spring Pivot.*—From Fig. 8:

$$S=0·000287\,\theta+0·000051\,\theta^2 \quad . \quad . \quad (5)$$

(b) 0·660*in Cross Spring Pivot.*—From Fig. 8:

$$S=0·000064\,\theta+0·000039\,\theta^2 \quad . \quad . \quad (6)$$

Combining equations (5) and (6), and assuming that the variation with length of the value of S is linear, equation (7) was obtained:

$$S=(0·000357-0·000444l)\theta+(0·000055-0·000024l)\theta^2 \quad . \quad . \quad (7)$$

Note.—If l is expressed in cm, then

$$S=(0·000907-0·000444l)\theta+(0·000140-0·000024l)\theta^2 \quad . \quad . \quad (8)$$

Values of S were calculated from equation (7) for various angular rotations of the cross spring pivots on which the experimental determinations were made. It will be seen from Table II that the empirical formula gives values for S which agree reasonably well with the experimental values:

Comparison of Results of Investigation with Theoretical and Experimental Investigations by Other Workers

Relation Between Stiffness and Geometric Size of 90 deg. Cross Spring Pivot.—Eastman[1] states that the formula given below and derived

TABLE II—*Experimental and Calculated Values of S*

Length of spring strip	Angle of rotation	Shift of initial axis of rotation per inch length	
		Experimental values	Values calculated from empirical formula
$l$in	θ	S	S
0·158	5	0·0027	0·0027
	10	0·0078	0·0080
	19	0·0237	0·0239
0·410	5	0·0024	0·0020
	10	0·0069	0·0062
	20	0·0214	0·0215
	25	0·0307	0·0325
0·660	5	0·0013	0·0013
	10	0·0047	0·0045
	20	0·0173	0·0169
	29	0·0349	0·0347

from the theory of bending may be applied to symmetrical cross spring pivots under pure torsion only:

Bending moment $M=n\frac{E'I\theta}{l}$, i.e., stiffness $K=n\frac{E'I}{l}$

. . . . . (9)

where n=number of spring strips.

Eastman's theoretical analysis gives no restrictions on the use of this formula, except that it applies only to small angles of rotation.

In the present investigation, spring strips having lengths up to about ¾in are used, and it is shown that the simple formula (9) is not generally applicable to such short lengths. Fig. 6 shows that formula (9) may give results up to about 25 per cent in error. The reason for this discrepancy is associated with the fact that the effective length of the strip is greater than its measured length, because of non-rigid clamping.

Most of Wittrick's[2] theoretical analysis applies to cross spring pivots acted on by external loads, as well as by a torque and is not discussed in this paper.

Haringx's[3] theoretical analysis gives values which agree to an accuracy of 4 per cent with the practical investigation given in this paper, provided the angular rotations are less than 20 deg.

Young's[4] work was done on spring strips ranging from 1½in to 3in in length and from 0·0085in to 0·012in in thickness. When his empirical formula is applied to the sizes of spring used in the present practical investiga-

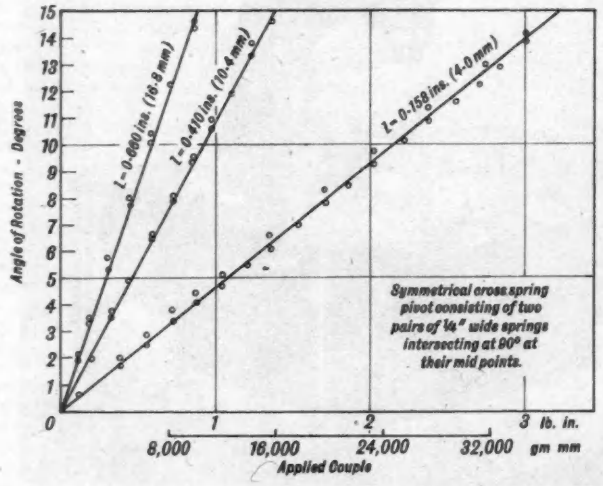


FIG. 5—*Relation Between Applied Couple and Angle of Rotation for Various Lengths of 0·010 in. thick Strip*

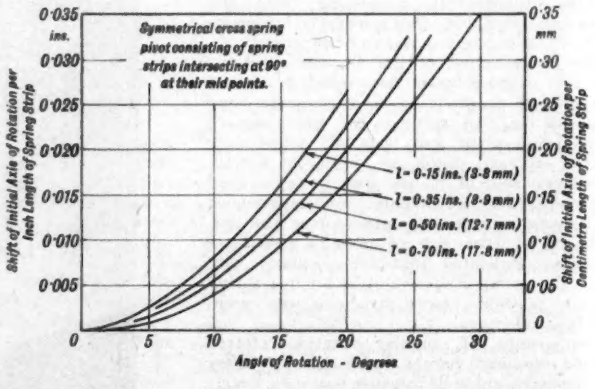

Symmetrical cross spring pivot consisting of spring strips intersecting at 90° at their mid points.
Shift of Initial Axis of Rotation per Inch Length of Spring Strip
Shift of Initial Axis of Rotation per Centimetre Length of Spring Strip
ins.
mm
l=0·15 ins. (3·8 mm)
l=0·35 ins. (8·9 mm)
l=0·50 ins. (12·7 mm)
l=0·70 ins. (17·8 mm)
Angle of Rotation - Degrees

FIG. 7—*Empirical Curves Giving Relationship between Movement of Initial Axis of Rotation and Angle of Rotation*

tion, the results agree to within 7½ per cent for small angles of rotation.

Movement of Initial Axis of Rotation.—Neither Eastman nor Wittrick deals with the movement of the initial axis of rotation of the cross spring pivot. Haringx, however, has calculated this movement from theoretical considerations and gives the following formula:

$$\text{Movement of initial axis per inch length of spring} = \frac{\sin\theta/2}{\theta/2(\text{radians})} - \cos\theta/2 \quad . \quad (10)$$

The values obtained from his formula, expressed as movement of initial axis per inch length of spring strip, are shown by the dotted line in Fig. 8.

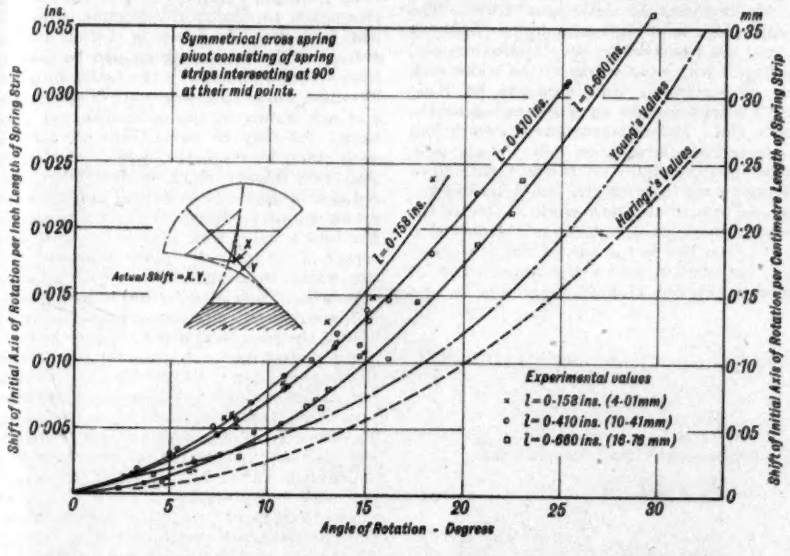

Symmetrical cross spring pivot consisting of spring strips intersecting at 90° at their mid points.
Actual Shift = X.Y.
l = 0·158 ins.
l = 0·410 ins.
l = 0·660 ins.
Young's Values
Haringx's Values
Experimental values
× l = 0·158 ins. (4·01mm)
○ l = 0·410 ins. (10·41mm)
□ l = 0·660 ins. (16·76 mm)
Shift of Initial Axis of Rotation per Inch Length of Spring Strip
Shift of Initial Axis of Rotation per Centimetre Length of Spring Strip
Angle of Rotation - Degrees

FIG. 8—*Experimental Values Showing Relationship between Movement of Initial Axis of Rotation and Angle of Rotation*

The experimental results obtained by Young, which are also shown in Fig. 8, led him to the following empirical formula:—

$$S \times 10^3 = 0{\cdot}4133\theta - 0{\cdot}01225\theta^3 + 0{\cdot}0012676^5 - 0{\cdot}00000750^4 \quad . \quad . \quad . \quad . \quad (11)$$

It will be seen that Young's experimental results agree reasonably well with those obtained in the present investigation for small angular rotations up to about 5 deg. In general, however, the experimental curves of the present investigation indicate that for such short lengths the movement of the initial axis of intersection of the cross strips, expressed in inches per inch length of spring strip, is dependent on the length of the latter.

Conclusions

This paper applies to the 90 deg. symmetrical cross spring pivots of sizes used in measuring instrument design, of lengths up to ¾in and thicknesses up to 0·020in. It has been found experimentally that the torque applied to the pivot is directly proportional to the angular rotation it produces; this statement applies to angular rotations up to 15 deg. to 20 deg., or to applied torques of 6 lb-in, whichever is reached first. The experimental results show that the stiffness, i.e., applied torque per radian rotation, for a cross spring pivot consisting of two pair of cross springs, may be expressed by the formula:

$$\text{Stiffness } K(\text{lb-in/rad.}) = 4\frac{E^1 I}{(l+0{\cdot}035)},$$

where $E^1 = 27{\cdot}5 = 10^6$ lb/in², and I and l are expressed in the inch system of units.

Curves of stiffness K, plotted on a base of spring strip thickness for a variety of lengths, and calculated from the above experimental formula, are given in Fig. 9 for the benefit of designers.

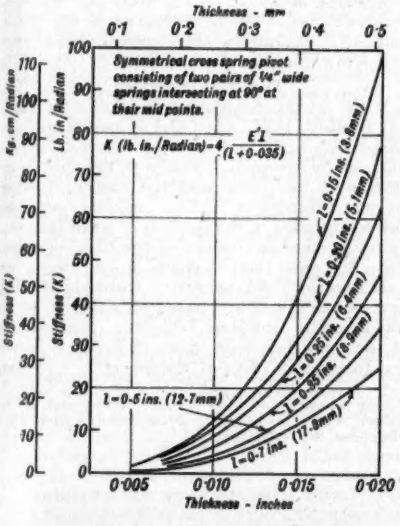

Symmetrical cross spring pivot consisting of two pairs of ¼" wide springs intersecting at 90° at their mid points.
K (lb. in./Radian) = 4 E'I / (l + 0·035)
l = 0·15 ins. (3·8mm)
l = 0·20 ins. (5·1mm)
l = 0·35 ins. (8·4mm)
l = 0·35 ins. (8·8mm)
l = 0·5 ins. (12·7mm)
l = 0·7 ins. (17·8mm)
Kg. cm/Radian
Lb. in/Radian
Stiffness (K)
Thickness - mm
Thickness - inches

FIG. 9—*Empirical Curves of Stiffness/Thickness for Various Lengths of Spring Strip*

The experimental results also show that the movement (S) of the initial axis of rotation of the cross spring pivot may be expressed by the formula:

$$S(\text{in/in length of spring strip}) = (0{\cdot}000357 - 0{\cdot}000444l)\theta + (0{\cdot}000055 - 0{\cdot}000024l)\theta^2,$$

where l is expressed in inches and θ in degrees.

Curves based on the latter empirical formula giving the relation between the movement of the initial axis of rotation and the angular rotation, are given in Fig. 7 for a variety of lengths of spring strip.

Acknowledgments

The authors desire to acknowledge the assistance afforded in some of the preliminary work by Mr. D. B. Spalding, and in the design of the adjustable cross spring pivot by Mr. D. C. Barnes.

The work described above was carried out as part of the research programmes of the Mechanical Engineering Research Organisation and the National Physical Laboratory, and this article is published by permission of the Directors.

References

[1] Eastman, F. S., "The Design of Flexure Pivots, *Journal*, Aeronaut. Sci., 5, 16–21 (November, 1937).
[2] Wittrick, W. H., "The Theory of Symmetrical Crossed Flexure Pivots," *Austral. J. Sci. Res. A.*, Physical Sc., 1: 121–134, 1948.
[3] Haringx, J. A., "The Cross Spring Pivot as a Constructional Element," Appl. Sci. Res. A1, 313–332, 1949.
[4] Young, W. E., "An Investigation of the Cross Spring Pivot," *J. Appl. Mech.*, 11, A 113, 1944.

Iron and Steel Institute Meetings

The engineers' group of the Iron and Steel Institute is arranging for a meeting of junior engineers (below the age of thirty-five) to be held at Ashorne Hill, Leamington Spa, on Tuesday and Wednesday, October 23rd and 24th. Mr. C. H. T. Williams will preside. Those attending the conference are asked to arrive at Ashorne Hill at 4 p.m. on October 23rd, and from 5 to 7 p.m. there is to be a discussion on "Electric Overhead Cranes for Iron and Steel Works," based on a short paper by Mr. J. Baker, managing director of Joseph Booth and Bros., Ltd. After dinner, at 8.30 p.m., Sir George Binney, of United Steel Companies, Ltd., will lecture on "The Importance of Commercial and Foreign Relations to the Iron and Steel Industry." On Wednesday morning, October 24th, the subject for discussion is "Accident Prevention in Iron and Steel Works," the matter being introduced by a paper by Mr. J. Brown, accident prevention engineer, Stewarts and Lloyds, Ltd., Corby. The conference will end at noon.

The autumn meeting of the Iron and Steel Institute is to be held at 4, Grosvenor Gardens, London, S.W.1, on Wednesday and Thursday, November 21st and 22nd, with the president Mr. Richard Mather, in the chair. On the first day, the morning session will begin at 10 a.m. and the following papers will be discussed:—"The Crystal Structure of Graphite in Cast Irons," by Mr. W. S. Owen and Mr. B. G. Street; "The Carbide Phase in Iron-Carbon-Silicon Alloys," by Mr. W. S. Owen; "Metallography of Carbon in Silicon-Iron Alloys Containing 4 per cent Silicon," by Mr. E. D. Harry; and "The Variation in Electrical Properties of Silicon-Iron Transformer Sheet," by Mr. S. Rushton and Mr. D. R. G. Davies. At the afternoon session, at 2.30 p.m., a symposium on "Stresses in Moulds" is to be discussed, followed by papers entitled "Ingot Heat Conservation: Ingot Mould Temperature Measurements," by Mr. R. T. Fowler and Mr. J. Stringer; and "Ten-Ton Ingot Moulds: Comparison of Design and Conditions of Use," by Mr. A. Jackson. At a morning session on Thursday, November 22nd, from 10 a.m. to 1 p.m., the papers for discussion are:—"The Production of High-Purity Iron and Iron Alloys on a 25-lb Scale," by Mr. B. E. Hopkins, Mr. G. C. H. Jenkins, Mr. H. E. N. Stone, and Mr. H. G. Short; "Tensile and Impact Properties of Iron and Some Iron Alloys of High Purity," by Mr. W. P. Rees, Mr. B. E. Hopkins, and Mr. H. R. Tipler; "Physical and Mechanical Properties of Segregates in Two Alloy Steels," by Mr. H. M. Finniston and Mr. T. D. Fearnehough; "Structural Transformations in the Tempering of High-Carbon Martensitic Steels," by Mr. K. H. Jack; and "Magnetic Analysis of Iron-Carbon Alloys: the Tempering of Martensite and Retained Austenite," by Mr. J. Crangle and Mr. W. Sucksmith.

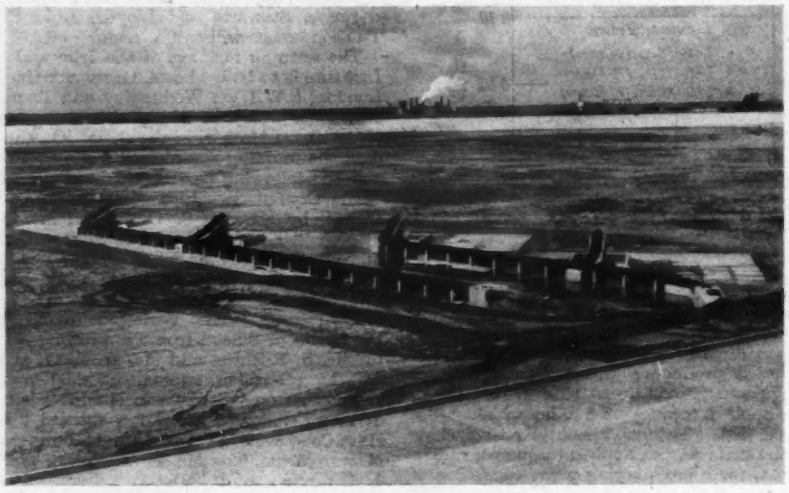
Symposium on Corrosion of Buried Metals

A symposium on "The Corrosion of Buried Metals," which has been organised by the Iron and Steel Institute, the British Iron and Steel Research Association and the corrosion group of the Society of Chemical Industry, will be presented at 4, Grosvenor Gardens, London, S.W.1, on Wednesday, December 12th. There will be two sessions, beginning at 10 a.m. and 2.30 p.m., at which Sir Charles Goodeve, F.R.S., will preside. The papers included in the symposium are:—"Tests on the Corrosion of Buried Iron and Steel Pipes," by Mr. J. C. Hudson and Mr. G. P. Acock; "Investigations on Underground Corrosion," by Mr. K. R. Butlin, Mr. W. H. J. Vernon, and Mr. L. C. Whiskin; "Cathodic Protection," by Mr. K. A. Spencer; "Cathodic Protection of Buried Metal Structures," by Mr. R. de Brouwer; "Corrosion of Buried Copper and Ferrous Strip in Natural and Salted Soils," by Mr. G. Mole; and "Tests on the Corrosion of Buried Aluminium, Copper and Lead," by Mr. P. T. Gilbert and Mr. F. C. Porter.

The William Girling Reservoir in the Lee Valley

IN our issue of September 7th last, reference was made on the Seven-Day Journal page to the inauguration of the Metropolitan Water Board's new reservoir in the Lee Valley. A more detailed account of the design and construction of this reservoir, which is one of the largest in the Board's possession, is given in this article.

The two reservoirs at Chingford were originally part of a scheme for Lee Valley storage laid before the Royal Commission on Water Supply to the Metropolis, presided over by Lord Balfour, in 1893. The proposals eventually took shape in three instalments, the first of which (the East and West Warwick reservoirs, Walthamstow) was authorised in 1894 and the second (the Banbury and Lockwood reservoirs, Walthamstow) in 1897. Powers for the final instalment were obtained by the East London Waterworks Company in their Act of 1900. In 1908, a few years after the Metropolitan Water Board came into existence, the northern reservoir was commenced, the work being completed in 1913. This reservoir is known as the King George's reservoir. The southern reservoir was not proceeded with, but the necessary powers were kept alive by the Board's Acts and Orders.



INLET WORKS

In 1934 the construction of the southern reservoir was started, but for various reasons the work has only recently been completed. The southern reservoir, which has been named the William Girling reservoir, after the chairman of the Board, is situated immediately downstream of the King George's reservoir. Its northern wall lies practically parallel with the south wall of King George's reservoir, on the opposite side of Lee Valley Road, and the top water level of the two reservoirs is the same. The outlet works lead to a reinforced concrete conduit 84in in diameter, which leads past the Banbury and Lockwood reservoirs, and the Walthamstow reservoirs lower down the valley, to the Lee Bridge purification works. The storage capacity of the new reservoir is 3400 million gallons; that of King George's reservoir is 2729 million gallons, which is very much larger than that of the remaining ones in the Lee Valley. By comparison, the Board's largest reservoir is the Queen Mary reservoir, near Staines, which has a capacity of 6679 million gallons.

In common with the Board's other reservoirs, the William Girling reservoir is formed by an earthen embankment around its perimeter, with a core of puddled clay in its centre which extends downwards to key into the London clay which forms a watertight floor. The maximum height of the embankment is about 42ft, and the reservoir is, very approximately, pear shaped with inlet works at the wider end, which is upstream and adjacent to King George's reservoir, and an outlet tower at the opposite end. Before constructional work had been started, the River Lee had already been diverted into a channel on the eastern side of the King George's reservoir, but it meandered across the site of the new works. One of the first tasks, therefore, was to extend the diversion channel down beside the site of the new reservoir. This work involved the construction of a concrete channel 11,900ft long, with a weir at its downstream end (Flanders weir), and two balanced radial flood gates. The intake is from this channel at the upstream end of the reservoir. A pumping station will be constructed near this point, with fully automatic electric control to utilise all the flow when it is required, up to the maximum intake capacity of 150 m.g.d. It is not necessary to allow a flow of compensation water at this point, since the statutory minimum flow of 5 m.g.d. required for navigation is taken higher up the Lee, where a navigation canal, known as the Lee Navigation, branches off, and leads down the western side of the two reservoirs.

A flood-relief channel was constructed all the way along the western side of the reservoir to take flood water from the Lee Navigation at Keids weir, and also an overflow channel, about 2300ft long, leading from a spillway on the Lee Navigation at Ponder's End lock to the relief channel, which it joins at Keids weir. The relief channel joins the River Lee diversion channel near the south end of the reservoir, downstream of Flanders weir.

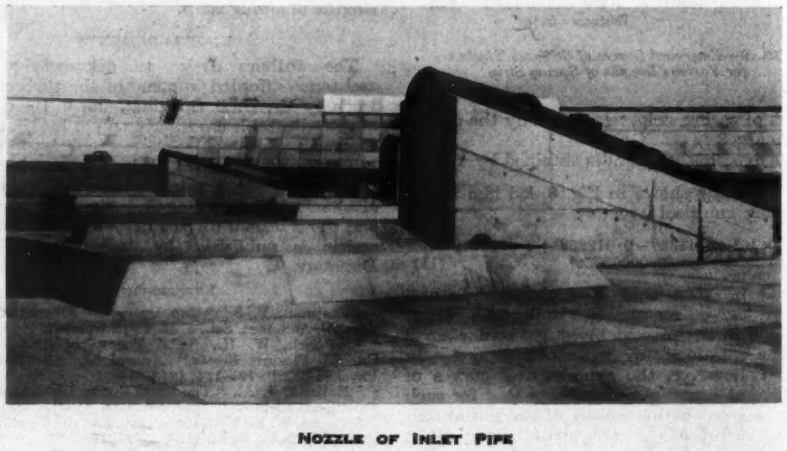
Later on, when the proposed 75in raw water main from the Thames Valley to the Lee Valley (Hampton to Chingford) is built, a main will lead from it to the pumping station mentioned above, so that the reservoir can be filled from that source if the flow of the Lee is insufficient. The inlet works themselves are of some interest, and are shown in the accompanying illustrations. As may be seen, there are two pipes, each 48in in diameter, and each branching into two inlets. Each of the inlet pipes is reduced in diameter at its end to form a nozzle, giving an inlet velocity of about 8ft per second. The inlet nozzles, which are at the north-eastern corner of the reservoir, point westward, so that the water entering the reservoir promotes a circulation from east to west along the north wall and, hence, a circulation round the northern half of the reservoir, which, it may be recalled, is the widest part. A secondary circulation in the southern half will be caused by this primary circulation and also by the action of the draw-off tower, so that stagnant areas are avoided. The velocity of the water entering through the jets is such that for comparatively little expenditure of energy, i.e., 1ft of pumping head, sufficient entrainment is achieved. Another interesting point about the inlet nozzles is that they are inclined upwards at an angle of 15 deg., to give entrainment at different levels in the reservoir, thus controlling thermal stratification, with its consequent adverse effects on the quality of the water during the summer months. The problems of circulation in open storage reservoirs were studied with a model of the Board's proposed Walton South reservoir, and the inlet design for the William Girling reservoir was based on the knowledge thus obtained.

The outlet tower is a reinforced concrete structure, and is illustrated opposite. It is a dry tower, and water can be drawn off at four levels, as shown on the diagram. There is a valve house at top of the tower, in which the manually operated headstocks of the four valves are situated.

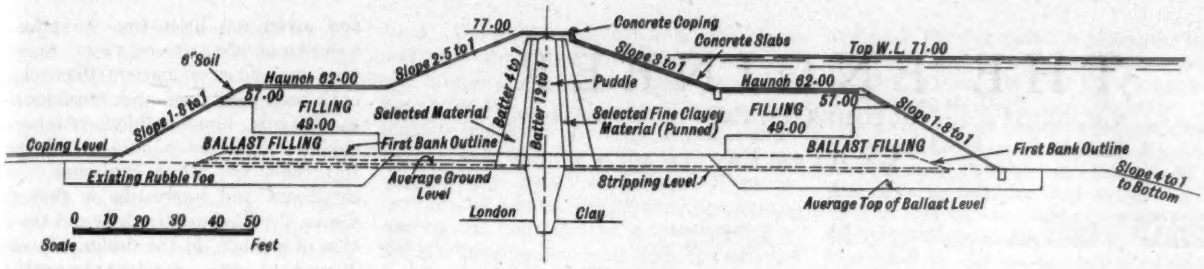
THE EMBANKMENT

Work on the reservoir was started in 1934, but in July, 1937, when the embankment was about 26ft high, serious slips occurred, necessitating its redesign. The war followed soon after work had been restarted, causing further serious retardation. The original set-back due to the slips in the bank is of some interest, however, since it was one of the first occasions when the analytical methods of soil mechanics were applied in this country; the design for the new embankment was based on a report which was made by Professor Terzaghi. The analysis of the bank has been given in a paper before the Institution of Civil Engineers*; however,

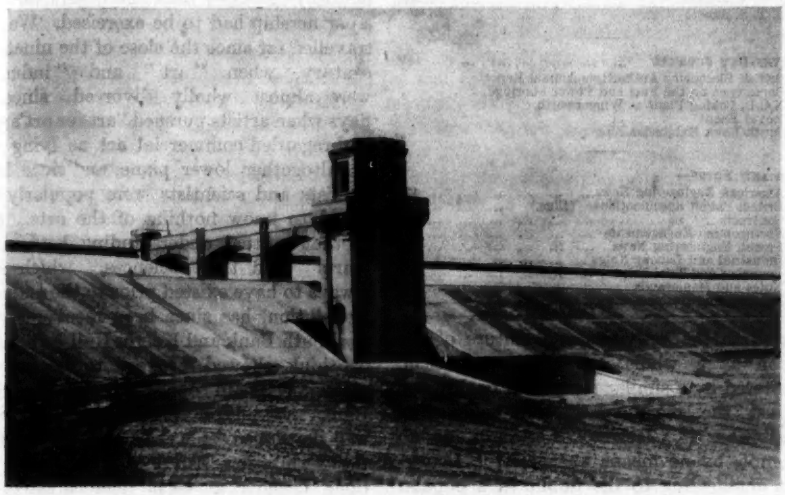
* "The Analysis of the Failure of an Earth Dam During Construction," by L. H. Cooling and H. G. Golder, Paper No. 5324, *Journal*, Institution of Civil Engineers, November, 1942.



NOZZLE OF INLET PIPE



CROSS SECTION OF EMBANKMENT AS BUILT



OUTLET TOWER AND CONCRETE-FACED EMBANKMENT

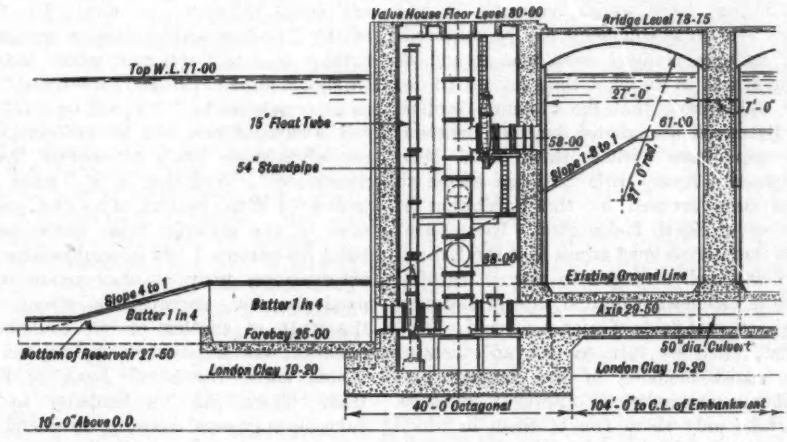
a brief account of the failure is given herewith.

The original design of the embankment is shown in the diagram below. The London clay, which is stiff and impermeable, is about 40ft thick, the top of it lying from 10ft to 30ft below ground level. A stratum of gravel overlies the London clay, and above it is a weak layer of clay known as yellow clay. Above the yellow clay is the topsoil, which was removed before the embankment was built. The selected filling next to the puddle core consisted mainly of the yellow clay, and the remaining fill was a mixture of yellow clay and gravel. This design was virtually the same as that used for King George's reservoir, so that its failure at a point close to that reservoir, was naturally unexpected. As mentioned previously, the failure occurred when the embankment was 26ft high; a length of about 300ft of the outer slope moved outwards some 14ft, parts of the top of the embankment falling about 2ft. The slip surface appeared to pass through the centre of the yellow clay. It may be noted that one of the properties of clay is that its shear strength increases with time when it is under pressure. It is remarked in the paper referred to above that at the time of the slip most of the embankment material had been in position only about thirty-seven days, and the mean shear strength of the yellow clay was 2·0 lb per square inch. For samples taken eight months later, however, the mean shear strength under 26ft of embankment was 5·2 lb per square inch.

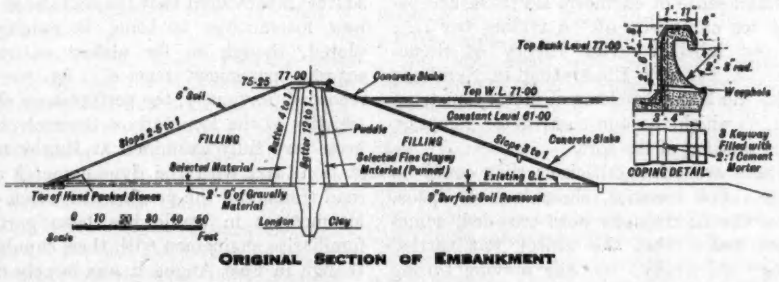
The diagram above shows a typical cross section of the embankment as it now stands. It may be noted that some of the material already in place has been left to form the centre part of the base of the embankment, and that on each side of it the stratum of yellow clay has been excavated and replaced by gravel. The shape of the gravel "haunches" and the dimensions of the berms were fixed so that on any slip surface that was chosen the resisting forces were increased by the frictional resistance through the gravel to give a factor of safety of 1·5. The upper surfaces of the gravel haunches were of the shape shown so as to reduce the volume of gravel to a minimum whilst complying with the above condition. A mixture of 50 per cent of clay and 50 per cent of gravel constituted the remainder of the fill, the gravel being incorporated to give some frictional resistance, but care was taken to avoid the formation of "lenses" of gravel, where water would have been able to accumulate, and affect the shear strength of the clay adversely.

As may be observed, the inner surfaces of the embankment are protected with a 4½in or 6in lining of plain concrete, cast in slabs about 10ft square, supported at intervals on the embankment by "kneelers" and surmounted by a wave wall. A central concreting plant was installed to construct the lining, aggregate being obtained from the site.

A clay pit was dug in the centre of the reservoir to supply the pug mills making the puddle core, the clay being dug by a cableway dragline excavator. The bulk of the excavation was carried out by scraper, or by dragline with Athey wagons, with bulldozers and angledozers to arrange the fill. The embankment contains about 5 million cubic yards of material, with some 300,000 cubic yards of puddled clay. Some ¾ million cubic yards of yellow clay was excavated and removed from the site, and about 50 acres of concrete slabs were laid. The design was due to Sir Jonathan Davidson, formerly the chief engineer of the Metropolitan Water Board, and the contractors were John Mowlem and Co., Ltd. The total estimated cost of the reservoir is £2,334,000. It will be a valuable storage reserve in supplying the eastern areas of London, but because of the diminishing resources of the River Lee, the complete answer to the question of supplying East London with water is not yet provided. Other works, principally the 75in raw water main from the Thames Valley to the Lee Valley, which was mentioned earlier, will be needed, and the Board is actively pursuing them as far as present circumstances permit.



DETAIL OF OUTLET TOWER



ORIGINAL SECTION OF EMBANKMENT

INSTITUTE OF INDUSTRIAL SUPERVISORS.—The Institute of Industrial Supervisors has recently inaugurated two new sections at Leicester and Stockport. Mr. F. J. Burns Morton, a director of A. E. Hawley, Ltd., is the president of the Leicester section, and Sir Patrick Hamilton, chairman of Henry Simon (Holdings), Ltd., is president of the Stockport section.

THE ENGINEER

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SUMMING UP THE FESTIVAL

APART only from the Pleasure Gardens in Battersea Park, London, and possibly a few remaining manifestations still to be completed in the provinces, the Festival of Britain ended with the end of September. But it is too soon yet to assess at all completely what effect industrially, culturally or in other ways the Festival has had or is going to have in this country or what have been its repercussions abroad. Posterity must be left to weigh up how far its success can be compared with that of the 1851 Exhibition, upon whose centenary it was held. Yet some comments can be ventured. For instance, judged upon the ground of their fitness to do what they set out to do, few will dispute that the Pleasure Gardens at Battersea are almost beyond criticism. All who have visited them have been delighted. Again little criticism seems to have been aroused by the Exhibition of Science at South Kensington. Even scientists themselves must admit that the Exhibition was well arranged to give a truthful, even if a somewhat limited, interpretation of the particular fields of science covered.

But when we turn to look at others of the shows included in the Festival programme unanimity of approval vanishes. To take only those two of them in which the works of engineers were portrayed, the Exhibition on the South Bank and that at Kelvin Hall, Glasgow, can any engineer feel, satisfactory though they were in many ways, that they could not have been bettered? Certainly it could be said, we think, of the South Bank that no specialist in any scientific or engineering subject could regard the treatment of his special subject as really adequate. But that criticism was, perhaps, inevitable from the first. For the site was quite inadequate in area to permit at all a full portrayal of the vast range of present-day knowledge and modern production. And even the specialist must admit that in a somewhat "popular" and limited way, he found the show interesting, instructive and stimulating in showing how his and many other fields of specialisation were related to the activities and culture of the nation as a whole. A similar criticism, countered by a similar reply, can be directed against the more specifically engineering Exhibition at Glasgow. Certainly, as an attempt, by no means unsuccessful, to present engineering to the public in a popular way it was attractive. But in neither of these exhibitions did it seem to us that the showmanship was always satisfactorily fitted adequately to explain the material on view. Upon that point an oversea contributor to our last issue, a contributor who made a special journey to this country to see the Festival Exhibitions, had some harsh, though enlivening criticism, to offer. He writes of the "professional exhibition designer or artist," who is "the man whose influence we should more particularly scrutinise," that, as a story-teller he "will not be content to tell a straight tale and his embellishments are often more likely to confuse than to illuminate"; and that he is "much more interested in the pattern of his own creation than in the material from which he will build his pattern." As generalisations these observations, truly as they relate to the particular, are, perhaps, too strong. But the truth of another of our contributor's remarks was self-evident to anyone who visited either the South Bank or Kelvin Hall. There was "a tendency to treat valuable engineers' drawings as though they were so much wallpaper." Again, our contributor was not alone in noticing how the problem of treating certain things utterly defeated the designers. They left "intractable objects such as screw propellers just lying around"! In one instance, at Glasgow, a failure to appreciate the down-to-earth common sense of engineers led to the acceptance for exhibition of "a trifling toy . . . gravely labelled 'The Theory of Structures, A Fantasy Illustrating in Symbolic Form the Main Problems of Metal Construction,'" which, as our contributor remarks, "did nothing of the sort."

There are other criticisms that could be made. For instance, sheer lack of space, when the Exhibitions were crowded, sometimes meant that the visitor was carried along, willy-nilly, by the moving throng and given too little time to take in the meaning of what was on view. Again, there were omissions of matters that might well have been mentioned and, more particularly at Glasgow, more ruthless pruning of the exhibits might have been all to the good. But these are minor criticisms. What is significant and interesting is that the two shows, the Pleasure Gardens and the Exhibition of Science, in the design of which predominance was exercised by artists and scientists respectively, proved more satisfactorily designed than the others, in which a partnership had to be exercised. We have travelled far since the close of the nineteenth century, when "art" and "industry" were almost wholly divorced, since the days when artists pursued "art for art's sake" and regarded commercial art as lying upon an altogether lower plane, and since industrialists and scientists were popularly supposed to know nothing of the arts. Some of that mutual understanding between the "arts" and the "sciences," which seems always to have existed prior to the Industrial Revolution, has since been recovered. But the South Bank and Kelvin Hall Exhibitions, we think, showed recovery to be not complete. Only in one field did the South Bank Exhibition show the partnership well developed. Maybe not everyone found the Exhibition buildings attractive. But their designs at least demonstrated how fully engineers and architects had collaborated to make use architecturally of new materials and new structural methods developed by engineers. It was hoped of the Great Exhibition of 1851 that it would help to raise the standard of British industrial design. It proved a vain hope then. But by bringing together scientists, industrialists, engineers and artists, besides many others, all in an attempt to express all facets of British activity as the related parts of a single cultural achievement, the effort put into the design of the various Festival exhibitions may well help towards the more complete attainment of that century-old object.

"BRITANNIA" LOCOMOTIVE PROWESS

INTEREST in the working of the first British standard "Pacific" locomotives has become heightened in recent months as successive engines completed at Crewe works have been drafted to a considerable variety of duties. As yet, with a total of only twenty-five in service, it can hardly be said that they are familiar objects, but it is worthy of note that for the first time in railway history locomotives of the same design are in regular service over routes so dissimilar in physical characteristics as Liverpool Street-Norwich, Victoria-Dover, Waterloo-Bournemouth, and Paddington-Penzance. From notes reaching us from a variety of sources it is evident that the usefulness of the new locomotives is being thoroughly explored, though so far almost entirely in express passenger service. As we have recorded previously, the performance characteristics of the locomotives themselves have been very fully examined at Rugby testing station, and with the dynamometer car in road trials, and the present utilisation of the locomotives in traffic has been partly to familiarise enginemen with their capabilities, though in East Anglia it was largely due to

their introduction that an accelerated service to and from Norwich was inaugurated this year. One could not, indeed, imagine a much greater contrast in running conditions than that between the fast, lightly loaded East Anglian trains, on which speeds up to 90 m.p.h. have been reported, and the haulage of the Cornish Riviera express in Cornwall itself, over a severely graded and curving road, where the maintenance of a running average of 39 m.p.h. between Plymouth and Penzance involves some exceedingly hard work when loads exceed 350 tons or so. Details of the running on all these routes will be studied closely by connoisseurs of locomotive performance, but already there appears to be one virtue common to them all—a notably low water consumption.

Keen observers have been quick to notice differences in general behaviour from that of previous designs in the same power classification, and one could spend considerable time searching through mechanical details of "Castles," "Royal Scots," "West Country Pacifics," and so on, to try and trace those observed differences to their origin. But in producing a new standard design that should be a synthesis of all that was best in previous British practice it is inevitable that there should be differences from most existing types of similar power, and in making for their clearly defined objective it seems evident, even at this relatively early stage, that Mr. Riddles and his staff have scored a resounding success. More interesting perhaps than the comparisons between the "Britannias" and their predecessors are the comparisons to be made between the work of the new engines themselves over different routes. Previously, in those arguments of a strongly partisan character that occur so frequently among railway enthusiasts, discussions upon the relative difficulty of express train schedules had little solid basis of fact, as the coal consumption of, say, a Great Eastern engine in hauling the Hook of Holland boat train down to Parkeston Quay each night was no criterion when comparing that duty with that of a Churchward 4-6-0 of the Great Western in working a two-hour express from Paddington to Birmingham. Even now, with "Britannia" class engines operating on both these routes, one has to make allowance for different qualities of coal, and different degrees of skill in driving and firing. But at least the basic machine is now the same, and is moreover one expressly designed to suit the widest possible variety of coal, and to be generally acceptable and welcome to the vast majority of footplate men. This latter point is nowhere more marked than on the Western Region; despite the existence, there, of a magnificent locomotive tradition, unchanged for more than forty years, the new engines which are so different in many ways from long-established Swindon practice have received a warm welcome.

Comparison of day-to-day running over various routes, with different locomotives of the same class, does not, however, even with meticulously accurate recording, give anything more than a rough indication. The Railway Executive has, in the form of the ex-L.M.S. mobile testing plant, a means of assimilating the running conditions, gradients, &c., of any route, and comparison of relative severity can be made on a truly scientific basis. The collation of such data takes time, and its eventual use for timetable revision will no doubt take even longer. Nevertheless, with the efficient general service locomotives which we now have in this country we can look forward to the time when the anomalies of train scheduling will be removed and a train service provided that is worthy of the motive power available. Notable progress has been made towards the standardisation of speed limits on curves; why could not standard minimum speeds eventually be established for running on the open road? In these difficult days of labour shortage the answer, so far as different parts of the country are concerned, probably lies with the civil engineers, though the increasing use of mechanised track maintenance methods may well go some way towards eliminating the most marked discrepancies of to-day. Meanwhile in the robust design and efficient performance of the "Britannias" the motive power departments are acquiring some excellent new tools for the job.

Obituary

GEORGE CHELIOTI

We record with regret the death of Mr. George Chelioti, which occurred at sea, on September 27th, while he was returning from South Africa on the "Pretoria Castle." Mr. Chelioti was a well-known industrialist and had been associated with the General Electric Company, Ltd., for nearly forty years.

George Chelioti was born in 1889 and was educated at Liverpool College. At one time his intention was to devote his career wholly to foreign commercial activities, but as a young man he became attracted to applied science and industry in this country. He joined the General Electric Company, Ltd., in 1912, beginning as assistant manager of its Robertson lamp works, and eventually becoming, in 1936, general manager of the Osram-G.E.C. group of works. That was still his major executive responsibility at the time of his death. Mr. Chelioti was appointed to the G.E.C. board in 1943 and was also a director of several of the company's associated and subsidiary concerns. He was particularly interested in all aspects of scientific management, and took a leading part in the work of the British Institute of Management and the Institute of Industrial Administration. Mr. Chelioti served on the councils of both those organisations and was also a member of the council of the Engineering and Allied Employers' National Federation.

J. E. MacLAREN

The British machine tool industry has suffered a loss by the death of Mr. James Edward MacLaren, which occurred at his home at 56, Oxford Road, Moseley, Birmingham, on Tuesday, October 2nd, in his fifty-fourth year. He had been managing director of B.S.A. Tools, Ltd., and its associated companies since 1946.

Mr. MacLaren, who was of Scottish ancestry, was born at Picton County, Nova Scotia, on November 4, 1897. He was educated at New Glasgow, Nova Scotia, and New Hampshire public schools and at Providence Technical College, and served a graduate apprenticeship with the Brown and Sharpe Manufacturing Company, Providence, R.I. During the first world war Mr. MacLaren was engaged in this country as an instructor at a Ministry of Munitions training centre, and when the war ended he joined the firm of Buck and Hickman, Ltd., as manager of its Scottish branch. In 1930 he was appointed a director of Buck and Hickman, Ltd., taking charge of its Birmingham branch. When war broke out in 1939 Mr. MacLaren's services were quickly in demand in connection with machine tool supplies. From 1939 to 1941 he was chairman of the machine tool control committee, a position which he relinquished to become Regional Controller for the Ministry of Supply in the Midland area. During the three years in which he held that office Mr. MacLaren instituted the "mutual aid" scheme, whereby manufacturers engaged on urgent production were enabled to interchange various tools and equipment, thus easing the acute shortage of machine tools. In 1945 Mr. MacLaren was appointed deputy chief of the economic division of the Control Commission of Germany. As stated above, he joined B.S.A. Tools, Ltd., as managing director in 1946, and earlier this year was elected to the board of the B.S.A. Company, Ltd.

Mr. MacLaren was a member of council of the Machine Tool Trades Association and a governor of the Birmingham Central Technical College. He was also a member of several professional institutions and a liveryman of the Worshipful Company of Carmen.

C. T. S. ARNETT

We have learned with regret of the death, in Manchester, on October 3rd, of Mr. C. T. S. Arnett, who had just retired from the position of Controller of the N.W. Division of the British Electricity Authority. He was sixty-three.

Mr. Arnett was born at Linthorpe, Yorkshire, and was educated at Durham University. He served an apprenticeship at the Heaton works of C. A. Parsons and Co., Ltd., and, on its completion in 1910, joined the North-Eastern Electric Supply Company, with which he remained for three years. In 1913 Mr. Arnett was appointed chief electrical engineer of Bolckow, Vaughan and Co., Ltd., a position which he occupied until 1927, when he became chief engineer of Pease and Partners, Ltd., Darlington. Four years later he joined the staff of the Central Electricity Board as operation engineer in its N.W. England and North Wales areas, and in 1939 he became manager of those areas. On the establishment of the British Electricity Authority in 1948, Mr. Arnett was appointed Controller of the N.W. Division.

Mr. Arnett was a member of the Institution of Electrical Engineers and served as chairman of its North-Western Centre in 1943-44. He was also a member of the Institute of Fuel. His services to the electricity supply industry were recognised by the award of the O.B.E. in the New Year Honours of 1948.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

TECHNICAL ADVANCES AND TRENDS IN ELECTRIC TRACTION

Sir,—In your issue for April 6, 1951, you review the "Electrification of Railways" report of a committee appointed by the Railway Executive and the London Transport Executive. Engineers interested in and working with railway electrification consider that some statements in this report would possibly mislead your readers. For instance, in any electrification scheme, the cost of the overhead equipment is a major portion of the total capital cost and thus any substantial reduction in this can affect a decision on economic grounds for any particular system. Every railway that has so far adopted the high-tension, single-phase

system has found that the cost of the overhead equipment has been half or less than half that required for a d.c. scheme. A further substantial saving has been shown on the cost of a.c. substations due to the better utilisation and consequently smaller number of these. It is for these reasons that railways have been able to justify an a.c. system. It is, therefore, amazing to find in the report that the committee considers that a.c. overhead track equipment is just as costly as that provided for d.c. The cross-sectional area of copper required is a function of the current flowing in the conductors, which is likewise a function of the voltage of the system. The copper required for an a.c. system is thus frequently found to be one-quarter that necessary for a d.c. system. With copper prices at the present level and with a reduction in the size of supporting structures possible, the cost of overhead must very obviously be considerably less than that required for any d.c. system.

The committee again seems to have been at some pains to show that the world trend to-day is away from a.c. systems. The reader is led to believe that during the last twenty years the only railways (with three exceptions) to decide on a.c. are those already heavily committed to this type of electrification. In fact, the very opposite is the case, and countries already heavily committed to d.c. schemes, such as France and New Zealand, have decided that future electrifications will be on the high-tension, single-phase system. Quite possibly d.c. is the correct choice for Great Britain, but it should be possible to justify that decision on its merits and not be necessary to belittle the universally accepted advantages of another system.

There was a time when a.c. locomotives cost quite a percentage more than their corresponding d.c. alternatives. When this was true then obviously the traffic density of any scheme had a large bearing on the choice of a system. The additional cost of rolling stock, if large quantities were required, could quite easily outweigh the savings obtained from the less expensive overhead. However, even this excuse can no longer be used, for several Continental manufacturers are now in a position to quote for a.c. locomotives at a lower price than the equivalent d.c. locomotive. The single-phase a.c. system of railway electrification has come to stay, and many readers will come to regard the electrification report as a swan song of a system that few will soon be able to afford.

C. A. MACKERSEY, A.C.S.E., M.I.E.E.,
Electrical Engineer,
New Zealand Government Railways
September 27th.

THE RETURN OF THE NATIVE

SIR,—If I interpret correctly the opening remarks in Mr. Livesay's letter you published in THE ENGINEER of September 28th last, it would appear that I am not alone in joining issue with him on his comments regarding present-day travelling conditions on the railways of this country.

May I plead on behalf of the "peculiarly mutton-headed fireman" of the American-built locomotive behind which I once travelled in France that the oil burned on such locomotives in their country of origin is possibly far superior in quality, calorific value, &c., to that consumed on similar locomotives running in France. It is also possible that were the incriminated fireman able to defend himself in your columns he might adduce some other, equally weighty reasons, why I had the misfortune to be coated with soot on that particular journey.

Really, Mr. Livesay seems to be unable to count his blessings. He can travel tens of thousands of miles on or behind oil-fired locomotives without suffering any inconvenience; he is able to retrieve his luggage complete and intact after it had been thrown out of a train at the wrong station, and last (but for me not at all least), he can decide right now not to travel by "Le Mistral," whereas I, besides other passengers, know full well in advance that we have no option but to use that particular train.

While I agree that British Railways were originally the subject of Mr. Livesay's ire (I would seem to run them very close for that distinction), it appeared to me of interest to illustrate the fact that besides British Railways, other railways, which like them have been unable to renew or increase their rolling stock and their locomotives for a period of over ten years, have to-day no option but to offer similar uncomfortable travelling conditions to their passengers. The latter, by the way, seem to have increased considerably in numbers, both in this country and abroad (paid holidays on a very large scale, dispersement of families due to war conditions and resulting changes of employment, &c.), while that of the trains at their disposal has either remained the same or has actually decreased compared with pre-war conditions.

The habits and customs of the travelling public have also undergone considerable changes under the stress and strain of circumstances, unpleasant experiences, shortages of supplies, &c., and passengers therefore nowadays prefer to keep an eye on their own belongings, rather than to have them loaded out of sight in a more or less distant van, as even an efficient check system, such as is used on the Continent, is not always a protection against loss.

Suitable interior design of the coaches can mitigate the resulting difficulties. Thus, many coaches of the Continental boat trains running between Victoria Station and the Channel ports, i.e., over a fixed distance without intermediate stops, are provided with spacious and easily accessible luggage racks or shelves in the vestibules, while the space beneath their seats is often kept free, thus providing additional storage space. Similarly, the electrified Swiss Railways also leave the space beneath the seats free from any heating appliances, these being run in ducts or channels alongside the carriage walls.

Accommodation for passengers wishing to join a train at intermediate stations *en route* may be provided by restricting the admission of passengers at the starting points of certain trains to those travelling a given minimum distance. Thus, the Italian "Rapido" trains will admit at their starting points of, say, Turin or Milan, passengers travelling to Rome (413 and 395 miles respectively) and beyond only.

As for Mr. Livesay's final remarks about French rearmament, I am afraid that I care little and know even less about its progress or otherwise, because with modern long-range guided missiles, atomic bombs and similar scientific toys, any country is being obliged to rely more and more on its own efforts, quite independently of what its allies may or may not be doing.

C. CARTY
London, W.C.1,
October 4th.

Commonwealth Jet Operations Conference

THE conference of representatives of Commonwealth and Colonial Governments, which opened in London on September 25th to consider problems associated with the use of gas turbine aircraft on Commonwealth routes, held its final session on Friday last. The chairman was Air Chief Marshal Sir Frederick Bowhill, G.B.E., Chief Aeronautical Adviser to the Minister of Civil Aviation. It is reported that the conference examined the advantages and characteristics of gas turbine aircraft and considered their effect on requirements for air traffic control, navigational aids, aerodromes, air-to-ground and point-to-point communications, ground services, and meteorological services (including upper air information). The conclusion was reached that it would be practical to introduce the "Comet" with existing facilities, but that realisation of its full commercial capabilities would require certain improvements to such facilities. The conference agreed that the existing network of radio sonde and radar wind stations for forecasting wind and temperature at heights up to 50,000ft must be expanded and that at certain stations the frequency of observations must be increased. Weather reports from aircraft would become even more important than at present. During the conference it was stated that flight trials with the "Comet" had so far shown that jet aircraft could be fitted into existing traffic patterns, but that improved systems would probably be needed later when jets were operated in greater numbers. This would require the use of improved radar systems and radio navigational aids giving accurate position indication over medium distances, and the development of a new form of long-distance navigational aid. The fact that jet aircraft like the "Comet" flew twice as fast as conventional piston engine types emphasised the need to put into effect quickly the improvements to fixed ground communications already agreed internationally. The same considerations had brought into prominence the desirability of air-to-ground radio telephony over long distances as well as short. Despite the greater sensitivity of gas turbine aircraft to tropical conditions, it was concluded that they could be satisfactorily operated from runways planned for piston-engined aircraft of comparable size and weight.

Literature

SHORT NOTICES

The Hot Working of Non-Ferrous Metals and Alloys. London: The Institute of Metals, 4, Grosvenor Gardens, S.W.1 (Monograph and Report Series, No. 9). 1951. Price 15s.—The contents of this volume consist of eight papers (with discussion) reprinted from the *Journal* of the Institute of Metals. The papers deal with the metallurgical aspects of the hot working of aluminium, magnesium, copper, lead and zinc, and of alloys of these metals. A factor to which all the authors drew attention was the necessity for having a satisfactory cast structure, free from porosity and internal stresses, and with a suitable grain size, as a starting point for all hot-working operations. Many aspects of the subject were discussed—the mechanism of deformation, factors affecting hot workability (including the effect of impurities), tests for hot workability, hot-working processes (forging, stamping, rolling, extrusion and rotary piercing), hot-working temperatures, and the effects of manufacturing conditions on the finished product. All the papers have a practical bearing on the production of high-grade, hot-worked material, and, conveniently assembled together as they are in this volume, they constitute an authoritative review of the subject that will be of value to all who are interested in the hot working of metals.

BOOKS RECEIVED

Journal of the Institute of Metals, Volume LXXV, 1948–49. Edited by S. C. Guillan. London: Institute of Metals, 4, Grosvenor Gardens, S.W.1. Price 60s.

Converting a Business into a Private Company. Fourteenth edition. By Stanley Borrie. London: Jordan and Sons, Ltd., 116, Chancery Lane, W.C.2. Price 3s. 6d.

Standard Methods of Analysis of Iron, Steel and Ferro-Alloys. Sheffield: The United Steel Companies, Ltd., 17, Westbourne Road, Sheffield, 10. Price 17s. 6d.

Economic Aspects of Atomic Power. By Sam H. Schurr and Jacob Marschak. London: Oxford University Press, Amen House, Warwick Square, E.C.4. Price 40s.

The Modern Approach to Electrical Machine Analysis

By W. J. GIBBS, D.Sc., M.I.E.E.

No. I

Scope of the Analysis.—Electrical machine analysis consists mainly of the derivation of equations of performance for all the various types of machines. Comprehensive analysis is impossible, and a preliminary segregation of the problems involved is necessary. For example, in the absence of salient poles, the air-gap surfaces are considered unbroken, as if the conductors were distributed in some ideal manner along the surfaces; the actual distribution of the windings and the presence of slot openings are treated separately as additions to the original analysis. Similarly, saturation effects have separate treatment.

The electrical elements of the machine are treated as two or more linear circuits in relative motion whose elements are "lumped." The machine does, in fact, behave in this way, and so the treatment is valid. The calculation and measurement of these lumped parameters—resistances and inductances—are considered design problems; although important, they are subsidiary to the main analysis. In what follows, only the analytical theory consisting of deriving equations of performance will be considered. An ideal theory is one applicable to every type of machine without exception; such a theory involves very difficult mathematical treatment. By detaching one class of machines forming a small minority, a common theory can be developed for all the others on a simple mathematical basis.

The class of machines detached for special treatment is exemplified by the inductor generator, and it includes all those machines that have salient poles or their equivalent on both sides of the air-gap. Such machines are not included in this analysis. In the vast majority of machines, saliency either does not exist or it is confined to one side of the air-gap. The existence of the salient poles disturbs the geometrical symmetry that would otherwise exist around the air-gap.

Symmetry and Balance.—Any dissymmetry in the structure of electrical machines raises difficulties in their analysis, and special devices have to be employed to surmount them. From an analytical point of view, the simplest type of machine is one with smooth stator and rotor surfaces at the air-gap, together with balanced windings on both members. A balanced winding on the stator means a balanced polyphase winding, but a balanced winding on the rotor may be either a balanced polyphase winding (which includes a squirrel-cage winding) or it may be a regularly wound commutator winding. The supply to the machine is said to be balanced when the phase voltages are equal in magnitude and when there are equal time intervals between successive phases. If all these conditions apply, the system is said to be completely symmetrical and the machine can be analysed in terms of one phase only.

But when there is any unbalance in the windings, the currents or the supply, or any lack of symmetry in the structure of the magnetic circuit, the machine is said to be unsymmetrical, and cannot be analysed in terms of one phase. To deal with the difficulties that then appear two well-known methods have been devised, namely, the method of symmetrical components and the two-axis method. The latter method is sometimes called for convenience the method of quadrature components. Each method has its own well-defined field of application; the one to be preferred depends on the nature of the dissymmetry. If the structure of the magnetic circuit is symmetrical and the unbalance is due solely to the application of unbalanced sinusoidal voltages, or the presence of unbalanced loads under steady state conditions, then the method of symmetrical components is the more appropriate. But if the unbalance is due to lack of symmetry in the physical structure of the magnetic circuit, the method of symmetrical components offers no advantages whatever. Quadrature components can be used when symmetrical components fail to simplify the analysis.

Quadrature components can only be used when the structural dissymmetry is confined to one member—either stator or rotor; in other words, it is essential that one side of the air-gap should be geometrically symmetrical, if not electrically. It is convenient to consider the symmetrical member to be the rotor; whether it is so in fact can be disregarded, for the analysis of the machine depends only on the relative motion, and makes no distinction between which member is stationary and which is rotating. If, as in this analysis, the salient poles are considered to be on the stator, the quadrature components are fixed in space and all conceptions are simple.

Method of Approach.—The historical development of a theory is not often the best or the most logical approach to the theory, and the usual presentation of the two-axis theory suffers from want of clarity, chiefly because it follows the lines of its original development. The treatment to be given here is less complicated and more satisfying; it also gives a more direct approach to the theory and avoids the historical path. Since the true concepts behind the two-axis theory are mathematical, this interpretation clears up many of the difficulties inherent in the historical approach. One result is that the salient pole polyphase synchronous machine stands clearly revealed as the fundamental machine from which nearly all others can be derived, and the analysis therefore opens with it.

The Fundamental Machine

Salient-Pole Machines.—For simplicity, a two-pole machine is assumed, because the same analysis applies irrespective of how many poles there actually are in the machine. The salient-pole member is regarded here as the outside stationary member, although in practice it is usually the rotor; this viewpoint is a matter of convenience, and is quite justifiable. The polyphase armature windings are thus on the inner rotating member.

The unwound machine is represented by Fig. 1, from which it is clear that there are two axes of symmetry, one through the axis of the pole called the direct axis, and the other through the centre of the interpolar space called the quadrature axis. The rotor, of course, has an infinite number of axes of symmetry, but the method to be used depends on there being electrical balance as well as geometrical symmetry on the rotor.

The normal procedure is to build up from physical conceptions a picture of the operation of the machine in terms of the quadrature component quantities. From this physical conception the equations are deduced, and because, by assuming constant

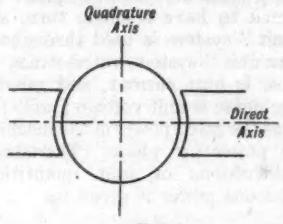


FIG 1

speed, they are linear they can be readily solved. But the transformation of the currents and voltages from the quadrature components to the actual phase quantities is difficult to prove rigorously, and assumptions about the structure of the machine are made. In the present analysis the more logical method is adopted of basing the mathematics on the real phase quantities; they are replaced by the two-axis quantities at a later stage.

Conversion to Two Phases.—Fig. 2 shows the winding arrangements of a salient-pole polyphase synchronous machine. It has one field winding f, wholly in the direct axis, and on the rotor a balanced polyphase winding, here shown as a three-phase winding. For the present it will be assumed that there are no damper circuits of any kind. Later, the effects on the equations of adding damper circuits will be shown and explained.

Since the armature windings are balanced, they can be described mathematically in terms of one phase only; but, owing to the

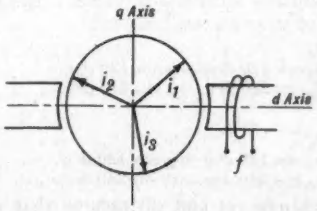


FIG 2

presence of salient poles on the stator, it is more convenient to replace the three-phase winding by a balanced two-phase winding. The three-phase windings can be denoted by the numerals 1, 2 and 3, and the two-phase windings by the letters a and b.

Then the relations between the two sets of currents can be derived as follows:—

In the three-phase system, let

$$i_1 = I_m \cos \omega t$$

where ω is the supply frequency in radians per second. Then

$$i_2 = I_m \cos (\omega t + 120 \text{ deg.})$$
$$i_3 = I_m \cos (\omega t + 240 \text{ deg.}).$$

In the two-phase system, let i_a be in phase with i_1, so that

$$k_1 i_a = I_m \cos \omega t,$$

where k_1 is a factor of proportionality to be assigned later. Then

$$k_1 i_b = I_m \cos (\omega t + 90 \text{ deg.})$$
$$= I_m \sin \omega t.$$

Therefore

$$i_1 = k_1 i_a.$$

Expanding,

$$i_2 = I_m(\cos \omega t \cos 120 \text{ deg.} - \sin \omega t \sin 120 \text{ deg.})$$
$$= k_1(i_a \cos 120 \text{ deg.} - i_b \sin 120 \text{ deg.}).$$

Similarly,

$$i_2 = k_1(i_a \cos 240 \text{ deg.} - i_b \sin 240 \text{ deg.}).$$

In the same way it can be shown that

$$e_1 = k_2 e_a$$
$$e_2 = k_2(e_a \cos 120 \text{ deg.} - e_b \sin 120 \text{ deg.})$$
$$e_2 = k_2(e_a \cos 240 \text{ deg.} - e_b \sin 240 \text{ deg.})$$

where k_2 is to be assigned later.

In the present analysis each phase winding is assumed to have a single turn, and the "per unit" system is used throughout. In the "per unit" system, rated r.m.s. current per phase is unit current, and rated r.m.s. volts per phase is unit voltage; unit power is defined as the rated power of the machine, and not the power per phase. Therefore, with these definitions of unit quantities, the instantaneous power is given by

$$P = \frac{1}{n}\sum_{1}^{n} e_n i_n$$

where n is the number of phases in the armature winding.

Thus, for the three-phase arrangement,

$$P = \frac{1}{3}\sum_{1}^{3} e_n i_n.$$

The result of substituting the two-phase quantities for the three-phase quantities by the equations is that

$$P = \frac{1}{2} k_1 k_2 \sum_{1}^{2} e_m i_m.$$

But by the definition of unit power for two phases,

$$P = \frac{1}{2}\sum_{1}^{2} e_m i_m.$$

Therefore $k_1 k_2$ must be unity in the "per unit" system, and each can be taken as unity. Thus, although i_1 differs from i_a in amperes, in the "per unit" system the two currents are numerically equal. The equations of substitution become:

$$i_1 = i_a$$
$$i_2 = i_a \cos 120 \text{ deg.} - i_b \sin 120 \text{ deg.}$$
$$i_3 = i_a \cos 240 \text{ deg.} - i_b \sin 240 \text{ deg.} \quad . \quad . \quad (1)$$

and

$$e_1 = e_a$$
$$e_2 = e_a \cos 120 \text{ deg.} - e_b \sin 120 \text{ deg.}$$
$$e_3 = e_a \cos 240 \text{ deg.} - e_b \sin 240 \text{ deg.} \quad . \quad . \quad (2)$$

Equations (1) and (2) assume that under all conditions the sum of the instantaneous currents and the sum of the instantaneous voltages are both zero.

Fig. 3 shows the arrangement with the two-phase armature currents. These currents

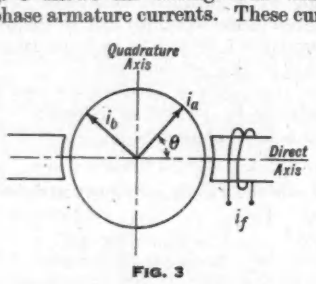


FIG. 3

are not only varying in time, but, in addition, are being rotated physically with the rotor conductors.

Let the angle between the axis of the rotor current i_a and the direct axis at any instant be θ. Consider first phase a winding, and its various voltages.

Fundamental Equations.—The equation of voltage of a coil moving in a varying field is

$$e = ri + p\phi \quad . \quad . \quad . \quad . \quad (3)$$

where r is the resistance of the coil, p is written to denote d/dt, and $p\phi$ is the total rate of change in the flux embraced by the coil, made up of the variation of the flux itself, and the motion of the coil in it. This is therefore the equation of voltage of any winding in the machine. Each winding is assumed to have a single turn, so that each component of flux can be replaced by the product of an inductance and a current. But the inductances are functions of time, and therefore p refers to the inductances as well as the currents.

From equation (3), therefore, the voltage equation of phase a is

$$e_a = p(L_{aa} i_a + M_{ab} i_b + M_{af} i_f) + r_a i_a \quad . \quad . \quad (4)$$

where r_a is the resistance of each armature phase and L_{aa} is the total self-inductance of the winding, M_{ab} is the mutual inductance between windings a and b, M_{af} is the mutual inductance between windings a and f. The principle of superposition invoked here is allowable because the inductances are not functions of the currents but only of time.

Expansion of the Variable Inductances.—The other two voltage equations will be considered later. Equation (4) is of little use as it stands because the law of variation with time of the inductances differs with different machines and is quite unknown. But though the variation is unknown, certain facts about it are known. Each inductance has a "continuous" variation that repeats, and is therefore cyclic. Thus it can be represented by a Fourier series. L_{aa} and M_{af} both have their maximum values when θ is zero, and therefore they must be represented by a cosine series; on the other hand, M_{ab} is zero when θ is zero, and must therefore be represented by a sine series.

The following, then, are the Fourier series:—

$$L_{aa} = A + B\cos\theta + C\cos 2\theta + D\cos 3\theta + \ldots$$
$$M_{ab} = E + F\sin\theta + G\sin 2\theta + H\sin 3\theta + \ldots$$
$$M_{af} = J + K\cos\theta + M\cos 2\theta + N\cos 3\theta + \ldots$$

In the axes of symmetry the various inductances are constants. Therefore, if the constant coefficients in the series can be determined, the variable inductances in equation (4) can be replaced by constant inductances.

Armature Winding Equations.—The basic assumption behind the two-axis theory is now made. It is assumed that the convergence of the various series is sufficiently rapid for all terms whose coefficients of θ are 3 and above to be omitted. The only justification for the assumption is that it leads to results that are reasonably borne out in practice. Thus, the expression for L_{aa} is assumed to be

$$L_{aa} = A + B\cos\theta + C\cos 2\theta$$

and the three constants can now be found from physical considerations. L_{aa} varies between a maximum when the axis of i_a is in the direct axis, and a minimum when it is in the quadrature axis. Thus, the minimum value occurs when θ is 90 deg., and not when it is 180 deg. Therefore, since the series is convergent, B must be zero; on the other hand, since L_{aa} is never zero and always positive, A must be positive.

Let the maximum value of L_{aa} be denoted by L_d and the minimum value by L_q. Then $A + C\cos 2\theta$ has to be equal to L_d at $\theta = 0$, and to L_q at $\theta = 90$ deg. Then clearly,

$$A = \tfrac{1}{2}(L_d + L_q)$$
$$C = \tfrac{1}{2}(L_d - L_q).$$

Write L_S for A and L_D for C, and the expression for L_{aa} becomes

$$L_{aa} = L_S + L_D \cos 2\theta \quad . \quad . \quad . \quad (5)$$

In the absence of saturation effects, assumed in this analysis, L_d, L_q, L_S and L_D are all constants. Although terms with 3θ and above have been omitted, equation (5) is strictly correct for the limiting values of $\theta = 0$ and $\theta = 90$ deg. This follows because the constants A and C were chosen to suit the known conditions at the axes of symmetry. In practice, L_q is usually about one-half of L_d, and with these relative values A is three times C. This ratio indicates that the convergence of the Fourier series is reasonably rapid.

The two mutual inductances can be dealt with in a similar manner. Since M_{ab} is zero both for $\theta = 0$ and $\theta = 90$ deg., the constants E and F must both be zero, leaving only the term $G\sin 2\theta$. The sign of G is determined by the fact that the mutual inductance between the two phases is due to the iron in the direct axis. When θ is less than 90 deg. the components of i_a and i_b in that axis are opposite to each other in direction, and therefore the sign of G must be negative. The magnitude can be determined from the knowledge that if the air-gap surfaces were smooth, making L_d equal to L_q, the term would have to disappear for all values of θ. From this it can be deduced that G must be numerically equal to L_D, and therefore

$$M_{ab} = -L_D \sin 2\theta \quad . \quad . \quad . \quad (6)$$

The conditions are entirely different for the field winding. M_{af} has its maximum value when θ is zero, and is itself zero when θ is 90 deg. Because of current directions it becomes negative in sign at the next maximum position of $\theta = 180$ deg. As the minimum value is zero, J must be zero and, to fulfil the other conditions, M—the coefficient of $\cos 2\theta$—must also be zero. Therefore K must be the maximum value of M_{af}, and it is usually denoted by L_{ad}. Thus,

$$M_{af} = L_{ad}\cos\theta \quad . \quad . \quad . \quad (7)$$

All the variable inductances relating to phase a have now been reduced to constant inductances multiplied by sinusoidal functions of θ or 2θ.

The substitutions of equations (5) to (7) into equation (4) gives

$$e_a = p[(L_S + L_D\cos 2\theta)i_a - (L_D \sin 2\theta)i_b + (L_{ad}\cos\theta)i_f] + r_a i_a \quad . \quad . \quad (8)$$

The equation for e_b can be found in a similar manner. But owing to the symmetry that exists it can be derived from equation (8). The voltage due to the mutual inductance between a and b is naturally unchanged, and $-L_D\sin 2\theta$ is carried unchanged into the equation for e_b, but is now multiplied by i_a. All the other terms are found by replacing e_a by e_b, i_a by i_b, and θ by $(\theta + 90$ deg.).

The result is

$$e_b = p[(L_S - L_D\cos 2\theta)i_b - (L_D \sin 2\theta)i_a - (L_{ad}\sin\theta)i_f] + r_a i_b \quad . \quad . \quad . \quad (9)$$

The Field Winding.—In terms of the variable inductances, the voltage equation of the field winding is

$$e_f = p(L_F i_f + M_{af} i_a + M_{bf} i_b) + r_f i_f \quad . \quad . \quad (10)$$

L_F is unaffected by the position of the rotor, and is therefore, in the broad sense, constant; at least, its time derivative is zero. Therefore, it is carried unchanged into the equation with constant inductances. L_F is the total inductance of the field winding, while L_f is reserved for the leakage inductance.

M_{af} has already been defined by equation (7). From physical considerations, M_{bf} must be the same as M_{af}, with the exception that θ must be replaced by $(\theta + 90$ deg.), and this produces

$$M_{bf} = -L_{ad}\sin\theta \quad . \quad . \quad . \quad (11)$$

Substituting for M_{af} and M_{bf} in equation (10) gives

$$e_f = p(L_F i_f + L_{ad} i_a\cos\theta - L_{ad} i_b \sin\theta) + r_f i_f \quad . \quad . \quad . \quad . \quad (12)$$

The Complete Equations.—The three equations (8), (9) and (12) are the required

differential equations of voltage for the salient-pole polyphase synchronous machine without damper circuits. It is very convenient and also instructive to write a set of equations such as these in the following compact form:

$$\begin{bmatrix} e_f \\ e_a \\ e_b \end{bmatrix} = \begin{bmatrix} r_f + L_f p & pL_{ad}\cos\theta & -pL_{ad}\sin\theta \\ pL_{ad}\cos\theta & r_a + p(L_S + L_D\cos 2\theta) & -pL_D\sin 2\theta \\ -pL_{ad}\sin\theta & -pL_D\sin 2\theta & r_a + p(L_S - L_D\cos 2\theta) \end{bmatrix} \cdot \begin{bmatrix} i_f \\ i_a \\ i_b \end{bmatrix} \quad \ldots(13)$$

There are three separate arrays or boxes in (13), and they are made up as follows. The dependent variables (the voltages) are put into one box, the coefficients of the independent variables into another box, and the independent variables themselves (the currents) into a third box. The boxes are then assembled as an equation, referred to as a single equation, although it is well understood to represent a set of equations.

By a simple rule, the separate equations can be read back from the arrays. It is best explained by a simpler example. Consider the following arrays:—

$$\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \cdot \begin{bmatrix} x \\ y \end{bmatrix}$$

This represents two equations, because there are two rows and two columns in the centre box. The first equation is

$$u = ax + by.$$

The right-hand side is formed by taking the top row of the centre box and multiplying each of its elements by the corresponding element of the column array and summing.

Similarly, for the second equation, the second row of the centre box is taken and the process repeated, giving

$$v = cx + dy.$$

This rule can be extended to arrays of any number of rows and columns, provided only that the number of elements in the column array is equal to the number of elements in the rows of the centre array.

Applying this rule to equation (13) gives the three equations (8), (9) and (12). For instance, taking the second row,

$$e_a = p(L_{ad}\cos 0)i_f + [r_a + p(L_S + L_D\cos 2\theta)]i_a - p(L_D\sin 2\theta)i_b,$$

and this is identically equation (8).

With practice, it is easier to read a set of equations when they are in this compact form, but there are many other advantages, some of which will become apparent later on. The arrays are also called matrices, and an equation such as equation (13) a matrix equation, but no knowledge of the theory of matrices is required to set out a group of equations as a matrix equation; all that is required is a knowledge of how to read the separate equations from the matrices. Equation (13) represents the required equations of the machine, and the next step is to proceed to their solution.

(To be continued)

Holme Moss Television Transmitting Station

THE television transmitting station at Holme Moss, which is to be opened to-day by the Postmaster-General, is the second high-power station completed under the B.B.C.'s post-war programme for the development of its television service. Holme Moss will bring television within the reach of 11 million people besides the 18 million already served by the existing stations at Alexandra Palace and Sutton Coldfield. Estimates based on the results of field tests show that average field strengths of 100μV per metre may be expected within an area, roughly rectangular, bounded northwards approximately by Lancaster and Bridlington, and southwards by Grimsby, Stoke and Rhyl. Broadly, the service area of the station is expected to include most of Lancashire and the East and West Ridings of Yorkshire, substantial parts of the North Riding, Lincolnshire, Nottinghamshire and Derbyshire, and the whole of the counties of Cheshire and Flint. Like the Sutton Coldfield station, Holme Moss will transmit the programmes as Alexandra Palace.

The station is built on a 150-acre site on the Holmfirth–Woodhead Road, about 9 miles south-east of Huddersfield. It is a remote site, but its elevation of 1750ft above sea level, surmounted by a 750ft mast, gives the aerial an elevation of 2500ft above sea level, which ensures a satisfactory transmission range.

Briefly, the station comprises a building accommodating the two main transmitters, a smaller building for two standby transmitters, a 750ft mast carrying the main transmitting aerial and a 150ft mast for a standby aerial, as shown in our first illustration. The main vision transmitter operates on a carrier frequency of 51·75Mc/s (5·8m), with a peak output power of 45kW, and is the most powerful television transmitter in the world. A frequency of 48·25Mc/s is used for the main sound transmitter, which has a carrier power output of 12kW. There are, in addition, standby vision and sound transmitters of 5kW and 2kW output power respectively.

To be in keeping with the character of the moorland upon which the station is built, the external walls of the buildings are constructed of hammer block random rubble gritstone, with sawn facings and dressings. In plan the main building, like its counterpart at Sutton Coldfield, is L-shaped. One block houses the main vision and sound transmitters, the other a quality-checking room, offices, and a canteen. To the north of the main building is a smaller building of similar construction containing a garage, substation and the standby transmitters.

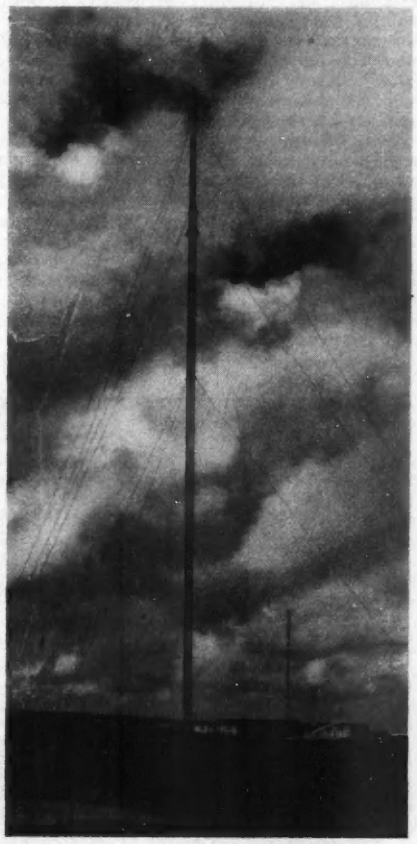
The outside walls are of cavity construction, the inner skin being built in 9in brickwork. Internal walls are generally of brick, fair-faced in technical areas and plastered elsewhere.

The sloping ground on which the building stands consists of shale, with an overlay of peat up to 8ft deep. This overlay was removed over the building site, and the floor level of the building has been kept high above ground level as a precaution against heavy snowdrifts, which are to be expected on this very exposed site in winter; voids beneath the floor accommodate ventilation ducts and wiring, and provide valuable storage space.

Parapet walls have been omitted from the roofs, to prevent snow from accumulating. All the floors are of concrete suspended construction, finished in "Korkoid" tiles, except for the cooler rooms and heavy stores, where granolithic has been used. The floor of the kitchen has been tiled. The quality-checking room has a carpeted wood floor; its walls and ceilings are covered with panels filled with glass silk to provide sound absorption. The roof of the building is of hollow precast concrete beams, covered with a vermiculite screed for insulation against excessive cold, and rendered waterproof by successive layers of bituminous felt.

To retain as much heat as possible in the building, double windows are provided throughout. The building is heated by warm air discharged in the form of waste heat from the transmitter cooling equipment; about 150kW is available from that source. When the transmitters are not in use heating is provided by means of thermostatically controlled convector heaters.

Water supplies for domestic and technical needs are taken from Yatcholme reservoir, some 800ft below the site. A stone built pump-house has been constructed to accommodate two electrically driven remotely controlled high-lift pumps. Owing to the site being upon a catchment area, it has been necessary for the B.B.C. to lay some 2 miles of earthenware drain to connect with the main sewer in Holmfirth.



TELEVISION STATION AND MASTS AT HOLME MOSS

The mast resembles the one at Sutton Coldfield, but is of more massive construction and is more heavily stayed to withstand the prevailing weather conditions. It has an all-up weight of 140 tons. The maximum downward thrust on the mast base under the most severe conditions is 350 tons. Location of the base is provided by a 2in diameter steel ball in a socket, which forms a pivot to allow angular movement of the mast in high winds. Up to the 610ft level the cross section is triangular, each face being 9ft across. Between 610ft and 710ft the cross section is circular. The eight tiers of four slots in the surface of this part will form an aerial for v.h.f. sound broadcasting, should this system be adopted at Holme Moss in the future. Above the circular section is a short square-section topmast which supports the television aerial. The steelwork was galvanised by the hot dip process after fabrication, the zinc coating amounting to about 2 oz per square feet of surface.

Four sets of stays support the mast. The stay ropes are of fully locked coil construction in steel with a breaking stress of 120 tons per

square inch. The chief merits of this kind of rope, which consists of concentric layers of circular wires surrounded by an outer layer of shaped interlocking wires, are the comparatively high modulus and the relative absence of inelastic stretching that can be obtained. The factor of safety is four under the most severe conditions, which include a coating of ice ½in thick throughout, simultaneously with a wind pressure of 65 lb per square foot at the mast head. This corresponds to a wind velocity of 125 m.p.h. at the masthead.

The transmitter block of the main building is divided longitudinally into three main areas by two partition walls. In the central area thus formed are the sound and vision transmitters, arranged in line, as illustrated. The area bounded by the partition wall behind the transmitters and the outside wall of the building is divided into three. The centre section contains the power conversion plant for the two transmitters, and the two end sections the valve cooling plant. By placing the valve cooling plant in rooms remote from the control room, the amount of noise reaching the control room is minimised.

Along the other side of the transmitter hall is the control room, placed approximately in the centre of the transmitter hall, and flanked by the vision and sound lines termination rooms.

Vision Transmitter

The vision transmitter has an overall length of 31ft, which includes a power distribution cubicle 10ft long. The transmitter is built in eight cubicles placed side by side. Viewed from the front, the radio-frequency stages are arranged in order of increasing power from left to right, and the modulator stages from right to left. Thus the radio-frequency output stage is next to the final modulator stage.

The radio-frequency section consists of a crystal oscillator followed by four amplifiers and a cathode-follower penultimate stage. The output stage, which is grid modulated, consists of two " BW165 " valves in a push-pull circuit. This stage is water cooled ; all other stages in the transmitter are air cooled ; a.c. filament heating is used throughout the transmitter except in the third amplifier and penultimate and output stages, which are supplied from a motor generator.

The modulator consists of an input amplifier, sub-modulator, clamp and main modulator. Shunt-regulated cathode followers and amplifiers, and the use of neon chains as interstage d.c. couplings, characterise the design. By the use of these circuits a band width of approximately 7Mc/s and a very low output impedance, as seen from the grids of the final r.f. stage—of between 7 and 8 ohms—have been achieved.

The transmitter has been designed to simplify fault location and maintenance. The input amplifier in the modulator, which is a small but complicated unit, is duplicated, so that a spare is immediately ready in the event of a fault. Similarly, many of the sub-assemblies are so arranged that they can be unplugged and removed for inspection and repair.

Power conversion plant for the transmitter is contained in an enclosure 35ft long which is located behind the transmitter.

High-voltage supplies are obtained from hot-cathode, mercury-vapour rectifiers. The phases of the 415V supply to the transmitter are stabilised and phase-balanced by three separate moving-coil voltage regulators. In addition, the high-voltage d.c. supplies from which constancy of output is important are provided with shunt valve stabilisers which result in the supplies having very low output impedances. The modulator is arranged to work with a single high-voltage supply of 3·5kV at 6A, which has both positive and negative terminals insulated from earth. A stabiliser is provided to give this supply a source impedance of 0·5 ohm and an additional stabiliser results in an impedance of one-sixth of an ohm between the negative supply terminal and earth. These low source impedances are necessary because the varying r.f. stage grid current returns through this supply and because the modulator anode current varies with signal level.

The smoothing circuit associated with the anode supply to the modulated r.f. stage is built to have a constant resistive impedance of 67 ohms from zero frequency up to 5Mc/s to give a linear modulation/frequency characteristic.

The filaments of the valves in the last three r.f. stages of the transmitter are supplied with direct current from a motor generator set. This set has an electronic regulator which keeps the output voltage constant to within 0·1 per cent and limits the filament current to 110 per cent of normal when starting from cold. All the remaining valves in the transmitter are a.c. heated.

Sound Transmitter

The sound transmitter, which is 15ft 6in long with a power conversion plant enclosure 14ft 3in long, is similar to the sound transmitter at Sutton Coldfield. It has a carrier power of 12kW and employs high-power class B modulation with the usual negative feed-back circuits, which result in total harmonic distortion figures of less than 2 per cent at levels of modulation up to 95 per cent, over the normal range of modulating frequencies. The carrier noise level is better than 60 db below 100 per cent modulation.

The anode and bias supplies are provided by rectifiers in the power conversion plant enclosure, which is behind the transmitter. All valve filaments are a.c. heated except that in the modulated output stage, which is supplied from direct current from a motor generator. This generator has an electronic regulator similar to the one associated with the vision transmitter. All the valves in the sound transmitter are air cooled.

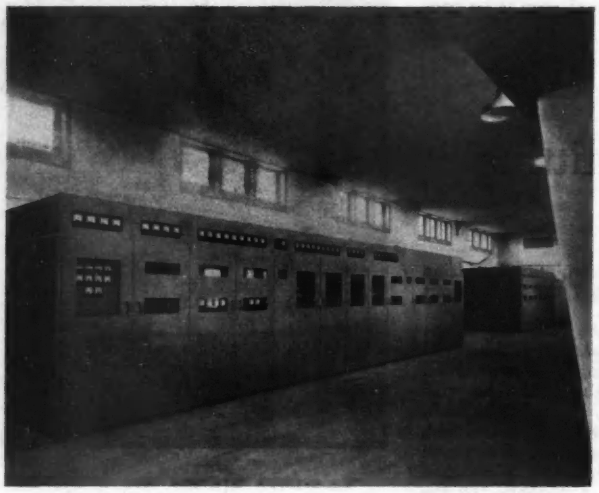
Each transmitter has its own valve cooling plant contained in a separate room. This arrangement has been adopted in order to isolate the noise of the cooling plant from the rest of the transmitter area. The air from each blower can be circulated round a closed system until its temperature is raised to a suitable value and then surplus warm air may either be circulated round the building or exhausted to atmosphere. Thermostatically controlled, motor-driven dampers determine the path that the air follows.

Distilled water, pressurised by nitrogen at 5 lb per square inch in order to exclude air, is circulated through the valve jackets and round a closed circuit for cooling the BW 165 valves in the modulated output stage of the vision transmitter. The circulated water is cooled in an air-blown radiator, the warm air from which may be used for heating the building.

Each transmitter is provided with a water-cooled test load of the dissipative line type in which the power is dissipated in the cooling water. The loads are supplied from individual test load cooling units located in the cooler rooms. These cooling units enable the water supplied to the loads to be raised quickly to the working temperature of 50 deg. Cent. and maintain this temperature constant in order to avoid variations in the load impedance. The load outlet water is cooled by passing it through coils immersed in large capacity water tanks located under the floor.

The output from the vision transmitter is taken to a vestigial sideband filter, which gives the transmission the required asymmetric characteristic, and thence to another filter where it is combined with the output from the sound transmitter. This arrangement differs from the one at Sutton Coldfield, where the sound and vision signals are carried up the mast by separate feeders and combined in a diplexer at the top of the cylindrical section. The method adopted at Holme Moss saves a feeder and also means that the combining filter can be adjusted and serviced far more conveniently. It also has the advantage that if for any reason the filter is incorrectly adjusted, the resulting reflections traverse such a short path that no double-image effect would be visible.

A concentric feeder having an outer diameter of 5in and a characteristic impedance of 51·5 ohms carries the combined outputs of the sound and vision transmitters to the aerial at the top of the mast. The feeder is built up from 12ft sections, with an expansion joint every 150ft to accommodate changes in length resulting



45kW Vision Transmitter (Left) and Sound Transmitter (Right)

Medium Power Transmitter Hall

from temperature variations. To prevent condensation, dry air is blown into the feeder from a unit located in the sound cooler room.

At the top of the mast the feeder arrives at a T-junction, one leg being fed directly to an unbalance-to-balance transformer, and the other leg via an extra quarter wavelength of line to a second unbalance-to-balance transformer. The two outputs from the second transformer are therefore lagging in phase by 90 deg. on those from the first transformer. The connections between the transformers and the aerial are so arranged that the dipoles in both tiers are phased 0 deg., 90 deg., 180 deg., 270 deg. Compared with the straightforward method of feeding all the dipoles in phase, this method not only increases the power gain of the aerial, but also results in a more constant input impedance over the frequency band.

The standing-wave ratio as measured at the output of the combining unit is 0·96 : 1.

A single array radiates the sound and vision signals. It consists of eight vertical folded dipoles arranged in two identical groups placed one above the other and separated by a distance of approximately one wavelength. Each of the four dipoles in the two groups is mounted on one face of the square-section topmast, the dipoles on opposite faces being approximately two-fifths of a wavelength apart. The average gain of the aerial in a horizontal direction is approximately 4 db. The dipoles are constructed of galvanised steel strip and incorporate 7½kW heaters to prevent ice formation. They are improved versions of those used at Sutton Coldfield, being wider and giving a better impedance/frequency characteristic.

A separate 150ft mast carries emergency sound and vision aerials for use if the main aerial or feeder system breaks down. These emergency aerials are fed with coaxial cables of 85 ohms impedance, separate cables being used for the sound and vision aerials. Owing to the limitations of the cable, the maximum power on the emergency aerials must be restricted to 20kW vision and 5kW sound. Switches are provided to enable a rapid change-over to be made from the main to the emergency aerial.

Both transmitters are operated from a single control desk in the control room, as illustrated. Windows between the control room and the transmitter hall afford the engineer on duty a clear view of both transmitters.

The control systems of both transmitters are conventional, being sequence interlocked and operated by means of toggle switches on the control desk. The correct functioning of the various interlocks in the complicated control circuit is indicated by lamps on three interlock indicator panels which are on the wall facing the control desk.

Meters on the desk indicate the voltage of the various power supplies and also the anode currents of the more important valves in the transmitter.

The central section of the desk houses a waveform monitor which can be switched to examine the output at various points in the modulator chain and also at monitoring points on the outgoing r.f. feeder. Also on the central section of the desk are switches which select the input signal fed to the transmitters, enabling either locally generated or line signals to be radiated. The locally generated signals normally consist of either test waveforms or the output from one of the two monoscopes. The monoscopes provide test card or apology captions as required.

Two 12in picture monitors mounted side by side in front of the desk display the picture at the modulator input and as radiated, thus enabling a direct comparison to be made.

The vision signal from London travels over coaxial cable via Manchester and is demodulated by G.P.O. equipment in the fully screened vision line termination room before being passed to the vision transmitter via the control room.

The sound line termination room contains the sound line termination and test equipment, and the rebroadcast receivers. A vision receiver is fed from an aerial directed on Sutton Coldfield and mounted at the 600ft level on the mast. It will be used only in the event of a breakdown on the cable link. The pictures from this receiver have so far been free from fading and of good quality, but occasionally suffer from slight car ignition interference.

Installed in a room adjoining the garage are a 2kW sound and a 5kW vision transmitter which can be connected to the main or reserve aerials by means of switches. These transmitters are independent of the corresponding equipment in the main building.

The vision transmitter is low-power modulated, having two stages of linear amplification following the modulated amplifier. The sound transmitter is a conventional high-power class B modulated unit.

Power Supplies

The station is supplied by the British Electricity Authority at 11kV, three-phase, 50 c/s over duplicate feeders which terminate on switchgear in the substation. The supply is transformed down to 415V and distributed from the low-voltage switchroom in the annexe to the transmitters and to the low-voltage switchroom in the main building, which contains the distribution switchgear for the auxiliary services. Two transformers are provided, each rated at 500kVA, one being a spare. The transmitter control circuits are provided with a 50V supply from metal rectifiers. A 240V battery supplies the emergency lighting system.

Principal Contractors

Plant.—Main and standby vision and sound transmitters and associated equipment, aerials, feeders and filters, Marconi's Wireless Telegraph Company, Ltd.; main low-voltage switchgear and 11kV/415V transformers, Brush Electrical Engineering Company, Ltd.; auxiliary low-voltage switchgear, Standard Telephones and Cables, Ltd.; emergency lighting battery, Alton Battery Company, Ltd.; wiring, S. Dickinson, Ltd. (Manchester); valve cooling and ventilation, Rosser and Russell, Ltd.; screening of l.t. room, A. E. Sudlow, Ltd.; coaxial cables to reserve mast, Telegraph Construction and Maintenance Company, Ltd.

Civil Engineering and Building.—Mast, British Insulated Callender's Construction Company, Ltd.; roads and buildings, John Laing and Son, Ltd.

Programme Links (Contractors to the G.P.O.).—Coaxial cables, translating equipment, Standard Telephones and Cables, Ltd.; amplifiers, General Electric Company, Ltd. (to G.P.O. design).

The G.P.O. was responsible for the installation and overall line-up of the links and also for the design and manufacture of the control equipment. The elevations of the station are to designs by Messrs. Wimperis, Simpson, Guthrie and Fyffe, FF.R.I.B.A.

Plant Extensions at Kembla Works, Australia

Despite manpower and material shortages, steady progress is being made at the Kembla Works of Australian Iron and Steel, Ltd., with the construction of the hot and cold strip mill and tinplate plant and of other major units, whose completion will increase considerably the production of iron and steel in Australia. The constructional work now in hand includes a third blast-furnace, an additional battery of twenty-four coke ovens, two new open-hearth furnaces, additional soaking pits, extensive alterations to the bloom mill, and the provision of the varied and complex ancillary equipment essential to the operation of the new units.

Of special interest is the No. 3 blast-furnace, which will be the largest in Australia and will rank with the largest furnaces in other countries. It is designed to produce 1500 gross tons per day and will supply hot metal for conversion into steel to feed the new hot and cold strip mill. The design, which incorporates the most modern equipment, was adopted in collaboration with the blast-furnace engineers of A. G. McKee and Co., of Cleveland, U.S.A. The new unit is being built in line with the two existing blast-furnaces and will provide the Kembla Works with blast-furnace capacity totalling 3400 gross tons per day. It has a hearth diameter of 26ft 6in with a working volume of 40,590 cubic feet, as compared with the 22ft hearth diameter and a working volume of 28,293 cubic feet of the existing No. 2 furnace, at present the largest blast-furnace in Australia. With the exception of a few items of equipment, such as the turbo-blower, the furnace is being manufactured in Australia and of Australian materials. The brick lining for the furnace proper is being imported from England, but bricks for the stoves and other auxiliaries are of local manufacture.

A new feature of the No. 3 furnace is the interlocking of electrical controls on the filling system to enable coke to be charged automatically from weighing hoppers in the desired sequence with ore and limestone. With this arrangement the scale car driver has to fill only the ore and limestone skips. The skip hoist winch will be driven by two 150 h.p. electric motors with Ward-Leonard system controls. The hoist, run at a maximum speed of 400ft per minute, will be capable of conveying a maximum load of 32,000 lb of ore. The raw materials distribution system will be of modern McKee design, incorporating a rotating distributor hopper and two bells. The bells are to be operated by pneumatic cylinders located in the hoist house and supplied with air from the cold blast, instead of being dumped by means of steam cylinders on the furnace top, as are the bells of the other two furnaces.

Welding is being extensively used in the construction of the new furnace, in particular for the shell of the furnace proper (comprising all-welded plate, 1¼in thick), the stove shells and the tuyere and bosh jackets. The columns supporting the main weight of the furnace stack are of special interest. Eight in number, they comprise steel beams welded to form an H section, 20in by 23in in cross section. In line with modern construction, the hearth of the furnace is enclosed in welded plates, 1½in thick, which are exposed the full height at the base of the furnace to facilitate external cooling and repair work. The cast house flow is to be of steel and concrete construction, 120ft long, and the system of runners provides for the use of five hot metal ladles and eight slag ladles. The tap hole is set out at an angle of 15 deg. to the cast house, which is equipped with a 20-ton capacity overhead crane arranged to approach the furnace as closely as possible and to reach the centre of the main tipping trough.

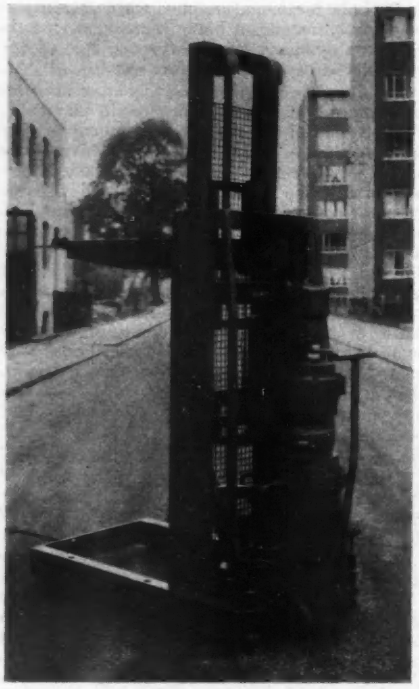
Another feature of this furnace is the provision of two slag notches at 90 deg. and 180 deg. respectively from the tap hole, each being fitted with a remote controlled mechanically operated bott. The blowing equipment consists of a Brown Boveri turbo-blower driven by a 12,000 h.p. steam turbine with a capacity of 100,000 cubic feet of air per minute at 30 lb per square inch pressure. Standing impressively in line with the furnace are the three stoves for preheating the air to be blown into the furnace, 120ft high and 27ft in diameter. They are of the two-pass design incorporating a checked tile of 2¼in square openings. A feature of the stoves' operating mechanism is the remote control of all valves from an elevated operating platform on the same plane as the cast house floor and the control room, in which all the instruments are to be housed. This floor will also be connected above yard level with the dust catcher and gas cleaning plant. The stoves' gas burners, situated below the operating platform, are to be power operated together with Askania air-gas ratio control, while the two 40in chimney valves of each stove are connected to an elevated main, which will be automatically regulated by a Brown controller in contrast with the manual operation used in the existing furnaces. A new design of furnace top has been adopted incorporating extended uptakes and a single downcomer, 10ft 7in in diameter, which enters the top of the dust catcher. The gas produced by the new furnace will be in the vicinity of 7½ million cubic feet per hour.

The building of No. 3 blast-furnace is a major undertaking of prime importance to the overall scheme of plant expansion at the Kembla Works. Important as it is, however, it is only one phase of the very large programme of new construction now being undertaken by the steel industry at Port Kembla, which, combined with the output of the merger company, the Broken Hill Proprietary, should increase Australia's annual production of steel from 1¾ to 2¼ million tons.

A Manual-Electric Stacking Machine

A NEW stacker, designed for both manual and electric operation, has been introduced by J. Collis and Sons, Ltd., Regent Square, London, W.C.1, to combine the advantages of the firm's manual-hydraulic and electric-hydraulic stackers. It is particularly intended for use in establishments where power is available and in adjoining areas where there is no power supply.

As can be seen from the 10 cwt capacity machine we illustrate below, the new unit is similar in appearance to the electric hydraulic model, and it incorporates the hydraulic method of operation. In it twin hydraulic control valves are used, one for manual and the other



STACKING MACHINE

for electric operation. The manual hydraulic system is actuated through a pumping movement with the towing handle, which operates through a parallel link motion housed between the wheel forks at the base of the machine. No selection mechanism is incorporated to change over from electric to manual operation and, if so desired, both operations can be carried out simultaneously.

The machine is fitted with the usual control lever for raising or lowering the load, and this lever is common to both manual and electric operation. The telescopic head machine, illustrated, is fitted with the usual automatic cut-out at the top and the bottom of the lift.

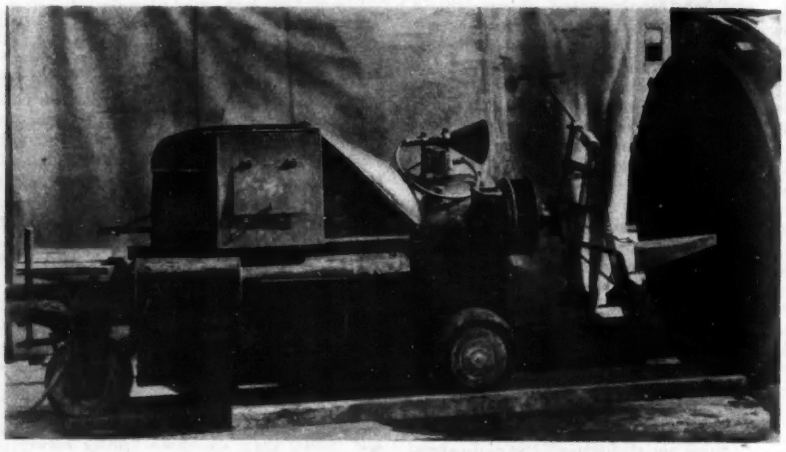
A Machine for Lining Large Pipes

AN interesting demonstration was given at Stoke Newington on September 24th and 25th last, involving the lining of water mains with cement mortar by a method used extensively in America and developed by the Centriline Corporation of New York. The method was originally developed to repair existing water mains and so restore their original carrying capacity at reasonable cost. The process may similarly be used for lining new mains after they have been laid.

The demonstration was carried out on a 90ft length of 75in diameter pipe, recently laid in an experimental length of tunnel driven at Stoke Newington for which Sir William Halcrow and Partners are the consulting engineers and Kinnear Moodie, Ltd., are the contractors. A further demonstration was carried out in a 36ft length of 48in diameter pipe laid on the surface. The cement lining was applied by a machine travelling through the pipe. The lining consists of thoroughly mixed cement mortar placed on the inside wall of the pipe by centrifugal force and mechanically trowelled to a smooth finish.

The machine, which is shown in the accompanying illustration, is a compact mobile unit operated electrically. Cement mortar from the hopper is forced by means of a worm feed into a rapidly revolving dispensing head, from which it is thrown off at high speed and distributed at the desired thickness upon the pipe wall. Slowly revolving arms are attached to a separate part of the head. Trowels attached to these arms follow directly behind the spread mortar and give a smooth finish and an even thickness to the lining as the machine moves along the pipe. Varying thicknesses can be applied from $\frac{1}{16}$in to $\frac{1}{4}$in and in mains from 24in to 123in in diameter. Speeds of lining from 1ft to 3ft per minute can be attained, depending on the thickness of lining required.

The demonstration was carried out by John Mowlem and Co., Ltd., by arrangement with the Metropolitan Water Board, and in conjunction with the Centriline Corporation of New York.



MACHINE READY FOR ENTERING 48 IN. DIAMETER PIPE

Water Pollution Research in 1950

THE annual report of the Water Pollution Research Laboratory, which has just been published, gives an account of some interesting experiments which were in progress during 1950, the year under review. This work has included experiments on sewage purification, some work on industrial wastes, and the continuation of a survey of the Thames estuary.

Experiments in the development of the process of alternating double filtration of sewage have so far been carried out using circular filters with rotating distributors. In order to simulate the working conditions in rectangular filters (in which the sewage distributors travel backwards and forwards along the length of the filter, with a consequently greater interval between successive applications than occur when circular filters are used) the distributors on one pair of the circular filters used in the experiments were driven mechanically at a much slower rate than is normal when rotation by reaction is used. It was found that lengthening of the interval between applications of sewage had no adverse effects on the process, but appeared to lead to a slight improvement in efficiency.

During twelve months of experimenting with the biological filtration in pilot plant of sewage at various rates between 100 and 1000 gallons per cubic yard of medium per day, it was found that at the highest rate eight times as much oxidisable matter was removed daily as at the lowest. A study was made simultaneously of the mechanism of biological filtration and it was found that the period of contact of sewage in the filters ranged from 110 minutes at 100 gallons per cubic yard per day to 20 minutes at 1000 gallons per cubic yard per day. There appeared to be a very rapid removal of oxidisable matter in the surface layers of the filters. Oxidation in the lower part of the filters followed a monomolecular law with a much higher reaction constant than has been recorded for other methods of treatment. A great improvement in the quality of the effluent was obtained during experiments at Luton sewage disposal works on mechanical filtration for the removal of humus from sewage effluent. Good results were secured with rapid gravity filters and with micro-straining plant.

A complete mixture of waste waters from a paper mill using mainly rag and hemp as raw materials, was successfully treated in a percolating filter during pilot plant experiments. Neutralisation of the strongly alkaline waste "black liquor" was unnecessary when it was mixed with other waste waters, the dilution and buffering effect giving a mixture of suitable pH value for treatment in the percolating filter. During these experiments the liquid was dechlorinated before filtration, but in later experiments it was found that small-scale filters could tolerate up to twelve parts of combined residual chlorine per million.

In an investigation of the effects of toxic substances on fish, one of the objects of which is to develop methods of assessing the toxicity of liquids, particularly trade waste waters, the period of survival of trout in a solution of potassium cyanide was observed. This period was found to be affected by the size of the fish and the conditions under which they had been kept before the test.

The scope of the survey of the Thames estuary, which was begun at the request of the Port of London Authority to investigate the causes of the deposition of silt, has been extended to include a study of the condition of the water in the estuary. Records of analyses and examination of the water covering the last fifty-five years and information on dredging and tidal phenomena, are being examined in order to learn the relative importance of the effects of changes which took place in that time on the sanitary condition of the estuary. Two marked changes which have shown themselves during the period are a steady increase in the temperature of the water and a decrease in the content of dissolved oxygen.

A fuller account of these various investigations is given in the report, which is entitled "Water Pollution Research, 1950," and is obtainable from H.M. Stationery Office at a price of 1s. 6d.

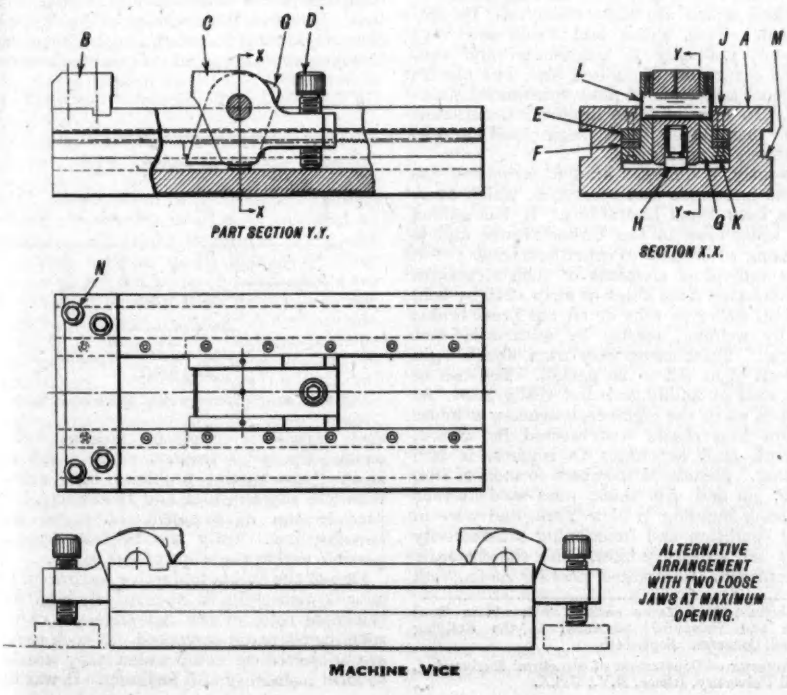
Machine Vice

THE vice illustrated by the accompanying drawing has recently been developed at Horwich locomotive works of the London Midland Region of British Railways. It was originally designed for use on milling machines and covers a much wider range of applications than a normal vice. The drawing shows the general construction. The body *A* is of forged mild steel and has a groove *M* on each side for ease of clamping to the machine table. A fixed jaw *B*, which may be serrated or smooth faced, is provided for work requiring repetitive settings, the jaw being secured to the body by four socket screws *N*. The loose jaw *C*, which is a special feature of the vice, is actuated by means of a socket head screw *D*. The racks *E* and *F* attached to the body *A* and the jaw carriers *G* enable rapid adjustment to be made for varying work widths. The racks are secured to the body and jaw carriers by cheese head set screws *J* and *K*. The jaw *C* pivots on a high-tensile steel pin *L* secured to jaw carriers *G*.

The gripping power and non-slipping qualities of the vice are attributable to the racks and the cam-like action of the serrated face of the loose jaw *C*. The cam action of the jaw is responsible for the downward pressure exerted on the work, which is a very desirable feature in vice work, but one not always achieved. The teeth of the serrated strips *F* and *E* are kept in mesh by reason of a spring-loaded mild steel plunger *H*, and the movable jaw can readily be moved into a new position by applying downward pressure by hand, and will resume its normal position when released by the upward pressure of the spring-loaded plunger *H*.

At the foot of the sketch is an alternative arrangement using two loose jaws, in place of one fixed and one loose. This provides a range of gripping widths from 0 up to approximately 12in with a single vice, the maximum width being obtained with each loose jaw at the extreme end of the body and the socket screws tightened on loose packing outside the vice ends. Any greater width can be effectively gripped by setting up two vices, each having one loose jaw opposite to each other. In such cases the bodies act as work parallels and two or more vices may be applied along the length of the workpiece.

The vice illustrated has been in use over a long period and has included the heaviest slab milling and negative rake milling at high feed rates. In all applications it has been found highly efficient and enjoys the full confidence of the machine operators. In addition, minimum effort is required to operate and loose packing bolts, &c., are obviated. Further, the vice is not limited to use on milling machines, but can be used on all general machining operations.



MACHINE VICE

The "RF" Class London Transport Coach

As part of London Transport's post-war plan to replace its entire single-deck fleet, the first of 263 new Green Line coaches went into service on October 1st on route 704, between Windsor and Tunbridge Wells.

THE "RF" LONDON TRANSPORT COACH

The new vehicle has a 7ft 6in wide full-fronted all-metal body on an A.E.C. Regal Mk. IV underfloor-engined chassis. In design and construction it is similar to the "RF" class sightseeing coaches, put into service earlier this year, except that full advantage has been taken of recent legislation to put 30ft long bodies on two-axle chassis.

The chassis arrangement is basically similar to that of the "TF" coach, with which vehicle London Transport pioneered in this country the underfloor engine. The majority of working parts in the transmission and axles are interchangeable with those of the "RT," with the result that servicing is facilitated. As with the "RT" vehicle, the new coach has a 16ft 4in wheel base, an engine of 9·6 litres developing 125 b.h.p., with fluid flywheel transmission, a four-speed air-actuated Wilson pre-selective gearbox with steering column control and compressed air braking.

A clean air supply for the engine is ensured by the location of the air intake above the driver's head, whence the air proceeds via a pipe-line to the engine.

The radiator is placed under the floor forward of the front axle, and air circulation is increased by an engine-driven fan.

In general lay-out and appearance the all-metal body, which is of the stressed inner skin design, follows the lines of the 5Q5 introduced in 1936, but having now a modern styling. The platform is enclosed by Peters air-worked glider doors, and the driver is isolated from the platform by a waist-high door and from the saloon by a full-length partition. Cab fittings include a heater and a wind shield adjustable to any desired position, a de-mister and two wind shield wipers. There are thirty-nine seats arranged in nineteen pairs facing forwards with a single seat, facing the nearside, immediately behind the driver's position. Tubular frames are provided with quickly detachable Dunlopillo cushion and squab units.

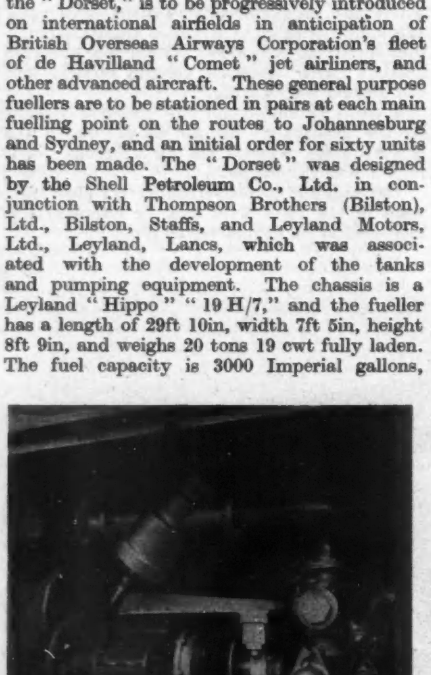
Ashtrays are fitted on each seat and the interior of the coach is warmed, as necessary, by a Clayton-Dewandre heater, which circulates warm air through a duct along the nearside.

Design for an Atomic-Powered Aircraft

THE United States Air Force has announced the award a contract for the development of an airframe suitable for an aeroplane to be propelled by a nuclear reactor. The contract has been given to the Consolidated Vultee Aircraft Corporation, of San Diego, California, makers of the "B-36," which is now the world's largest operational aircraft. The nuclear reactor for the craft is under construction at the gas turbine division of the General Electric Company. The Air Force announcement indicated that it might be a matter of years before aircraft driven by a nuclear reactor will fly. Andrew Kalitinsky, the former chief engineer of the Atomic Energy Commission's "NEPA" project (Nuclear Energy for the Propulsion of Aircraft), suggested a year ago to the Institute of Aeronautical Sciences that the intense heat of a nuclear reactor might be applied through a modification of the turbo-jet engine. Mr. Kalitinsky proposed that the combustion chamber of a turbo-jet engine, which normally burns kerosene, might be replaced by a nuclear reactor.

An Aircraft Fueller

An entirely new class of airport fueller, named the "Dorset," is to be progressively introduced on international airfields in anticipation of British Overseas Airways Corporation's fleet of de Havilland "Comet" jet airliners, and other advanced aircraft. These general purpose fuellers are to be stationed in pairs at each main fuelling point on the routes to Johannesburg and Sydney, and an initial order for sixty units has been made. The "Dorset" was designed by the Shell Petroleum Co., Ltd. in conjunction with Thompson Brothers (Bilston), Ltd., Bilston, Staffs, and Leyland Motors, Ltd., Leyland, Lancs, which was associated with the development of the tanks and pumping equipment. The chassis is a Leyland "Hippo" "19 H/7," and the fueller has a length of 29ft 10in, width 7ft 5in, height 8ft 9in, and weighs 20 tons 19 cwt fully laden. The fuel capacity is 3000 Imperial gallons,



PUMPING, PRESSURE-CONTROL AND MICRO-FILTERING COMPARTMENT

which can be delivered using either the "over wing" fuelling technique with two hoses each delivering 100 gallons per minute, or, alternatively, by "underwing" or "pressure" fuelling also at 200 gallons per minute.

Provision is also made for defuelling by either method for redistribution of the fuel load, for receiving and discharging fuel simultaneously, for filtering (10 micron), and for road "bridging" of supplies between an airport and a main depot. A single centrifugal pump is fitted which is driven by a power take-off from the road engine. The steel tank is of welded construction lined internally with aluminium. It is divided into five compartments and internal fittings are of aluminium alloy, argon-arc welded. The tank "breathes" to atmosphere through a vapour vent gallery fitted with a vacuum and pressure-relief valve, and there are seven accessible water and sediment drains within the system.

With "pressure" fuelling operations it was clear that manual control was insufficiently fast and reliable to deal with the pressure rise occurring when flow is shut down at the delivery hose, and automatic pressure control became an absolute necessity on high-speed integral fuelling from beneath the wing, where specified flow rates may vary from 50 to 200 gallons per minute and operating pressures from 25 lb to 50 lb per square inch, the allowable shut-down pressures being but 8 lb or 10 lb per square inch above operating pressures.

The "Dorset" is consequently fitted with a pressure-control valve which was designed by Shell Petroleum Company, Ltd. This device allows any desired fuel delivery pressure to be set in advance, the flow delivery pressure and shut-down pressure being thereafter automatically controlled.

It consists of a combined throttling and shut-off valve coupled to and controlled by two pistons working in opposition to each other. The effective pressure areas of these pistons and of the valve member are equal; thus the whole moving assembly is in static pressure balance. One piston works in a cylinder which terminates in an air chamber connected to a hand-operated air pump and a pressure gauge, and the other works in a cylinder which terminates in a fuel (or "monitoring") chamber with pipe connection to any point in the dispensing system where it is desired to control the pressure, i.e., the delivery hose reel. In operation, pressure in the air chamber is raised to the desired controlled pressure and the valve is forced to its open position. As the fuel pressure in the system rises at the control point, the pressure in the monitoring chamber rises accordingly, and when equal to that in the air chamber progressively closes the valve. Apart from adjusting the air pressure to that required, the valve is fully automatic in that it permits full flow until the delivery pressure rises, and meters the flow according to the off-take until the set pressure is reached, when it shuts completely. Our illustration shows the pumping, pressure-control and filtering units.

Arrangement of the valve member at an angle to the direction of fluid flow results in a calculated degree of dynamic disbalance, progressively tending to accelerate the valve towards the closed position as flow velocities increase.

In addition to safeguarding the aircraft's fuel system against excess pressures, the control valve permits the use of very much higher rates of flow through the truck's own pumping and metering system.

Thin-Walled, Cold-Formed Steel Structures*

By G. WINTER†

The field of use of conventional steel structures composed of hot-rolled shapes of the long-established types is limited by two factors: (1) in view of their shape they are not easily adapted to what may be called surface structures, i.e., walls, floors, roofs, and the like. They can and do support such plane elements, but they generally do not compose them; (2) in view of limitations inherent in the hot-rolling process, the thickness of such shapes of customary, overall dimensions cannot be reduced below certain limits, generally of the order of $\frac{1}{4}$in. For moderate spans and loads this results in the fact that sections cannot be produced which are light enough to be economical. Such spans and loads are very frequent, not only in commercial and residential structures of limited size, but also in the floors and roofs of more substantial structures. In view of these limitations, materials other than steel have been used almost exclusively in such cases.

Recently, a different kind of structural use of steel has made its appearance, which overcomes both these limitations. It has gained wide acceptance in the United States and is beginning to be used in other countries.

The individual elements of such structures are fabricated from sheet or strip steel by cold forming, either in rolls or on the press brake, and by welding, mostly by automatic spot welding. Thicknesses vary from about $\frac{1}{16}$in to about $\frac{1}{30}$in (12 to 20 gauge). The use of sheet steel in buildings is not really new. As far back as in the eighteenth century a house of thin iron sheets was erected in Tipton, England, and, according to reports, is still standing. Structural members formed of iron sheets, $\frac{1}{4}$in and $\frac{1}{16}$in thick, were used in 1855 in a bank building in New York, and were in sound condition and functioning satisfactorily nearly half a century later, when the structure was replaced. Corrugated steel for roofing and wall sheeting has been used satisfactorily for many decades.

The wider use of such members, except for roofing, had to await the development of fabricating devices suitable for mass production, i.e., the large press brake and spot welding, in addition to the cold rolling mills, which had been available earlier. Aside from these fabricating problems, however, special problems of design and analysis had to be met. The fact that design codes for conventional steel structures obviously were not applicable to these thin sections all but prevented their use on a large scale. To meet this need, the American Iron and Steel Institute, in 1939, sponsored a research undertaking at Cornell University, of which the writer has been in charge ever since, and which was to result, in 1946, in the Specification for the Design of Light-Gauge Steel Structural Members, issued by that Institute. This code has since gained national acceptance by the preponderant majority of local State and Governmental agencies concerned with such matters. The material used in such construction, sheet or strip of structural quality, has been defined by three pertinent specifications of the American Society for Testing Materials (designations A245, A246 and A303), in which are stipulated minimum yield points, ultimate strengths, permanent elongations and other characteristics necessary for satisfactory

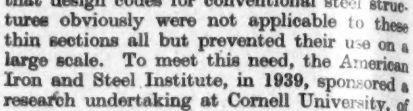


FIG. 1—*Light-Gauge Steel Structural Sections*

structural performance. With practical and legal obstacles removed by the introduction of such standards, the use of light-gauge steel for structural purposes has become very widespread.

It is utilised in two forms, viz., as structural shapes of more or less conventional outline (except for the small thickness), and as load-carrying panels for floors, roofs and walls. For the latter light curtain walls designed only for wind load, and non-carrying partitions are also increasingly fabricated from sheet steel. Figs 1 and 2 show some typical forms of both kinds.

The principles of design and analysis of such structures are not basically different from others. In the end the two fundamental laws, equilibrium of external and internal forces and compatibility of deformations, are the foundation of all structural science. (The "law" of elasticity, it will be noted, is not among them.) The special problems which face the designer of

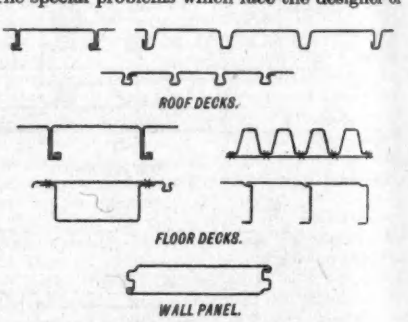


FIG. 2—*Light-Gauge Steel Decks and Panels*

such structures originate mostly, but not exclusively, in the thinness of the material. It is in these special problems that extensive research, experimental and theoretical, had to precede the development of sound design specifications. Only the briefest account is possible within the scope of this paper.

One of the main, distinctive features of light-gauge construction is the relatively large width-thickness ratio of the flat elements of which such members are composed. If such elements are subjected to compression they are liable to local instability and buckling. It was found

* Abstract from paper entitled "Trends in Steel Design and Research," presented at the Building Research Congress, Sept. 14th.

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that elements supported along only one longitudinal edge, such as the flanges of Figs, 1 *a*, *b*, *e*, *g*, *h*, and *j* fail or, at least, distort sizeably at the critical stress determined by the classical theory of elastic stability. Design stresses must be so adjusted as to provide an adequate margin of safety against such occurrence. In contrast, elements supported along both longitudinal edges, such as webs and flanges of Figs. 1 *c*, *d*, *f*, *i*, and *k*, even though they may develops light and often imperceptible buckling waves at stresses somewhat below the critical, do not fail at the critical stress but are capable of resisting considerable additional compression force in the "post-buckling" stage. The compression stress is then no longer uniformly distributed over the width of the flat element, and its strength can be computed by making use of the concept of the equivalent width in a manner not dissimilar to that employed in stressed skin construction in aircraft. Compression members composed of such thin, flat elements may fail either in local or in column buckling, a fact which correspondingly modifies the customary procedures of column design. Walls can be formed by attaching fibrous or other wall boards to both flanges of studs of the type of Figs. 1 *e* and *f*. In that case buckling about the minor axis, i.e., in the direction of the wall, is counteracted by the rigidity of the collateral wall material, which provides more or less elastic supports to the studs at points of attachment. To produce safe designs the required amount of such support had to be investigated. Local crushing of thin-walled beam webs at points of loads or supports represents a more serious problem than in ordinary construction. In elements of relatively large width-span ratio, such as in some of the deck sections of Fig. 2, non-uniform stress distribution may be caused by shear lag and must be accounted for in design. One of the simplest beam shapes that can be fabricated by cold forming is the channel (Figs. 1 *a*, *c*). The eccentric location of the shear centre which causes the channel beam to twist under transverse load makes it necessary to provide against such action by special bracing, whose required spacing and strength had to be clarified by special investigation. Similar research is now under way for Z-shaped beams (Figs. 1 *b*, *d*), which also tend to twist under transverse load.

This merely partial enumeration will give an idea of the scope of research that was required to produce the first design specification for light-gauge steel members, research which is still continuing in some phases. In addition to such structural investigations, considerable research was carried out on the severity of fire hazards prevailing in buildings and on ways to provide against those hazards, both with regard to light-gauge as well as to ordinary construction. A more rational approach toward fire protection has resulted, and it was shown that the fire protection that can be afforded with light steel panel construction is ample for all normal purposes.

Light-gauge steel construction has secured a substantial place in the building industry. Millions of square feet of decks and panels are installed yearly, from single-storey buildings largely or entirely made of such material to substantial heavy frame structures thirty and more storeys high in which light-gauge floor and, to an as yet minor degree, wall panels are widely used to decrease deadweight, increase floor space, accelerate construction and provide space for plumbing, wiring, heating (particularly radiant heating) and air conditioning. A similar, though somewhat more limited, development is taking place in the use of light-gauge structural sections (Fig. 1) for moderate-size structures, for wall and floor framing, roof trusses and the like. In fact, this development would have reached even larger proportions had it not been for the continued shortage of sheet steel prevailing in the United States since the last war.

OXYGEN LANCING IN ELECTRIC ARC STEEL-MAKING FURNACES.—In the article under this title which appeared in last week's issue, two photographs showing oxygen lancing were reproduced. The original photographs were supplied by Edgar Allen and Co., Ltd., of Sheffield.

American Engineering News

(From our American Correspondent)

Carbon Steel Artillery Cartridge Cases

Although a general of the American Ordnance recently pronounced the steel cartridge project of the last war "a complete flop," research and development has been carried forward to the point where now both the U.S. Army and the U.S. Navy are beginning to standardise steel artillery cartridge cases in sizes from 20mm to 155mm. A comprehensive review of the present state of the project is given by W. F. Stevenson, the civilian chief of the ammunition branch of the Chief of Ordnance Office, writing in *Steel*, July 9, 1951. Cartridge cases fabricated from steel have shown superior performance to cases of the same design fabricated from brass. For steel cartridge cases it has been demonstrated that non-heat-treated low-carbon steel, such as WD–1010 steel, will be satisfactory for cases required for low power weapons (e.g., the 75mm and 105mm howitzers) and that heat-treated medium carbon steel to WD–1030 specification, will be satisfactory for all other weapons now under consideration. Much higher physical properties, if needed, are attainable through the use of heat-treated alloy steels. Such steels can be extruded and drawn with little more difficulty than straight carbon steels. It has been established that the steel must be of good quality, well killed, uniform and relatively free of non-metallic inclusions.

Experience has shown that it is not possible simply to substitute steel for brass in a cartridge case production line. This procedure was tried during the last war when attempts to fabricate cartridge cases from steel on a production basis were only sporadically successful. To overcome the difficulties involved in the manufacture of steel cartridge cases, the development work in this field is now being conducted jointly by the U.S. Navy Bureau of Ordnance and the Ordnance Corps of the U.S. Army. An example of this co-ordinated action and policy is the establishment of joint Army-Navy steel cartridge case standby factories. The Ordnance Corps of the Army has standby factories for the production of artillery projectiles, bomb bodies, powder, high explosives and loading. The Navy Bureau of Ordnance has one standby factory for the manufacture of 40mm steel cartridge cases. This situation led the Bureau of Ordnance, slightly over two years ago, to propose the establishment of a joint Army and Navy standby factory primarily for the production of the Army 90mm and 105mm steel cartridge cases and for the Navy 3in and 5in steel cartridge cases. This factory is expected to be in operation in the autumn of this year. The establishment of this standby factory will permit the required flexibility in the control and adjustment of steel cartridge case manufacturing schedules. Except for the standby 40mm case works of the U.S. Navy in Detroit, the factory of the Norris-Thermador Corporation at Los Angeles, the Fulton Sylphon Company at Knoxville, Tennessee, the limited capacity of the Frankford Arsenal and the Naval Gun Factory in Washington, neither service has a facility for the war-time manufacture of steel cartridge cases for artillery.

The Naval Ordnance Factory at Louisville, Kentucky, was selected as the site for the joint standby factory. The contract covering the installation of equipment for steel cartridge case manufacture at this factory does not cover the development of suitable manufacturing methods. In order to establish such methods the U.S. Army Ordnance has taken the following steps: An industrial mobilisation study is being made for the development of a method of manufacturing the 90mm steel cartridge case, and contracts have been issued to develop the 75mm "skysweeper" and 76mm tank gun cartridge cases from steel. Furthermore, Frankford Arsenal has been asked to develop the 120mm steel cartridge case, and similar work has been initiated to cover the steel cartridge case for the 105mm howitzer. The standby factory will be laid out and equipped to make steel cases by the disc and cup method, with a provision for a change over to the cold extrusion from bar if that method should be adopted.

In addition to the development of manufacturing methods aimed specifically for use in the standby factory, the U.S. Army is now conducting other projects on steel cartridge cases. Two contracts have been issued relating to steel 20mm cartridge cases. One is with the Stoner Manufacturing Company of Aurora, Illinois, covering a process of cold extrusion from low carbon steel bar stock. In this process a deep cup is backward-extruded from a hot-forged slug, followed by one forward extrusion and one conventional draw. Another contract is with the Proctor Electric Company of Philadelphia, covering the conventional process of cupping and drawing from medium carbon steel plate. This company was one of the most successful manufacturers of 20mm cases during the last war. A novel aspect of the Proctor development is the forming of the extractor groove in the head of the case by pinching or cold working instead of by machining. This has overcome flange fractures, particularly at sub-zero temperature firings. Both companies have had successful results in ballistic tests of pilot batches and the development work is nearing completion. A contract has been completed with the Heintz Manufacturing Company of Philadelphia, covering a process of cold extruding from bar stock the 105mm howitzer steel cartridge case. Ballistic tests have shown the case to be satisfactory.

During the war, most steel cartridge cases were made from plate by the disc, cup and draw method—the method used for making brass cartridge cases. Some work was done in the substitution of a hot forged cup for the cup made from a disc, the hot forged cup being made from bar stock. The advantage of using bar stock instead of plate is in the reduction of the amount of steel required. Twice as many cartridge cases can be made from an ingot of steel if bar is used instead of plate. The yield from ingot to bar averages about 78 per cent; from ingot to plate it is 60 to 65 per cent. The yield from plate to round disc is about 71½ per cent, and from ingot to disc about 32 per cent. By careful blanking this figure can be increased to about 44 per cent. The number of press operations required to draw the 105mm howitzer cartridge case from a steel disc during the last war varied from eight to ten. This was reduced to seven press operations from bar by cold extrusion in the first successful attempt, and undoubtedly it can be further reduced by one operation. A hot forged cup generally replaces the first two press operations from a disc. The cold extrusion process generally replaces all press operations except "final draw," "head" and "taper." It is generally necessary to machine the outside of a hot forged cup to obtain the necessary concentricity or uniformity of wall thickness as well as the desired surface finish; which are required in the subsequent drawing operations. On the other hand, no machining is required for cold extrusion. Cold extrusion involves the use of punches and dies, but it differs basically from drawing. In the latter operation the case is formed by pushing the disc and subsequent cups through dies producing tensile stresses; cold extrusion forms the case by compressing the bar and subsequent cups in dies, causing a flow of the steel.

Since the manufacture of steel cartridge cases is inherently difficult and requires the use of heavy, long-stroke presses, not common in industry, studies are being made of cartridge case designs to overcome these deficiencies. For example, it has been felt for a long time that the recoilless gun cartridge cases could be made by using a pre-perforated sheet of steel, wrapping it into a cylindrical shape and fastening the lap by welding, brazing or other means, then fastening it similarly to a head piece. This multi-piece design is now being developed by several commercial concerns. The Frankford Arsenal is also investigating means to develop a multi-piece design for low-power weapons, 75mm and 105mm howitzers. A promising design comprises a spirally wrapped overlapping strip steel body portion, mechanic-

ally attached to a metal head piece. The joint in the wrapped body portion is unfastened, permitting it to expand when fired, then to contract and be extracted easily from the gun chamber.

In conclusion, it is stated that besides manufacturing difficulties, the Ordnance Bureau is confronted with a fundamental prejudice against steel as a cartridge case material, on the part of the using services. This feeling is understandable as the steel cases supplied during the last war were, in most calibres, definitely inferior in performance to brass cases.

Opening of the Delaware Memorial Bridge

The Delaware Memorial Bridge was dedicated by the Governors of the States of Delaware and New Jersey on August 15th and opened to general traffic on the following day. Erected as a monument to the members of the armed Forces from Delaware and New Jersey who were killed during the last war, the four-lane span over the Delaware River will accelerate vehicular traffic between New York, Washington and the South by eliminating the New Castle–Pennsville Ferry. The ferry has been a major traffic bottleneck which, in the past, has created bumper-to-bumper traffic blocks as long as 4 miles on both sides of the river. The ferry is to be purchased and scrapped by the State of Delaware. The 2-mile-long bridge, crossing a mile of water, joins Deep Water Point near Pennsville, New Jersey, with Pigeon Point, midway between Wilmington and New Castle, Delaware. On the New Jersey side, the bridge at present carries traffic from U.S. Highway 130, and later will serve as the southern terminus of the new New Jersey turnpike. On the Delaware side the bridge connects with U.S. Highway 40, the route to Baltimore and Washington, and U.S. Highway 13, the du Pont highway running south through Delaware.

With a clear centre span of 2150ft and two side spans of 750ft, the Delaware Memorial Bridge is the sixth longest suspension bridge in the world. It has a vertical clearance of 175ft above mean high-water level for a channel width of 1500ft, and the overall bridge length, between abutments, is 10,765ft. The substructure of the bridge, for which the Merritt-Chapman and Scott Corporation was the contractor, was completed in the summer of 1950. The American Bridge Company was the contractor for the superstructure and Howard, Needles, Tammen and Bergendoff acted as consulting engineers.

The Granby Pumping Plant, Colorado

The dedication by the Commissioner of Reclamation took place on July 20th of the Granby pumping plant, near Granby, Colorado, one of the key installations of the Colorado-Big Thompson project. It is the third largest pumping plant built so far by the Bureau of Reclamation, and it is exceeded in capacity only by the Grand Coulee pumping plant on the Columbia River and the Tracy pumping plant of the Central Valley project in California. The primary purpose of the Colorado-Big Thompson project is to divert surplus water from the Colorado River on the western slope of the Continental Divide to supplement the existing supply for land on the eastern slope. The secondary purpose is to generate hydro-electric power from the system wherever falling water offers a suitable opportunity. An estimated average quantity of 310,000 acre-feet is available each year for diversion from a point east of Grand Lake near the head of the Colorado River; yet such diversion, with the replacement storage proposed, will not encroach upon the present or future irrigation requirement of western slope lands in Colorado. This dependable supplementary supply will improve economic stability through reduction in drought hazards, and the cultivation of more abundant crops. The pumping plant lifts the project waters from Granby reservoir where they are stored following collection from the high reaches of the Colorado River, to a level where they will flow by gravity to the basin of the South Platte River on the eastern or Atlantic Ocean side of the Continental Divide. Only one-fourth of the 180ft height of the pump-house is above ground. The base measures 125ft by 56ft, while the upper floors are somewhat larger. The underground concrete structure has rounded or semi-circular ends to resist the considerable pressure of water and water-saturated earth surrounding it. Three vertical-shaft centrifugal pumps, each driven by a 5000 h.p. motor, raise the water from Granby reservoir to the Granby pump canal, involving a maximum lift of 186ft. The combined capacity of the pumps at maximum load will lift approximately 500,000 gallons of water per minute. After leaving the Granby pumping plant, the pumped water flows by gravity through a canal into Shadow Mountain Lake, which, in turn, is connected with the largest natural body of water in the State of Colorado, Grand Lake, and into the inlet of the 13·1-mile-long Alva B. Adams tunnel bored through the Continental Divide. From the outlet of the tunnel the water enters the system of siphons, tunnels and conduits which lead it through five power plants on the Eastern Slope of the Rocky Mountains. Having generated electric energy in the 3000ft drop from the outlet of the tunnel to the foothills of the Rocky Mountains, the water is led into terminal storage reservoirs for eventual delivery to the main tributaries of the South Platte River. Ultimately this water will aid in the irrigation of more than 1000 square miles of productive farmland in north-eastern Colorado. The three reinforced concrete intake tubes to the pumps from Granby reservoir are 7ft 3in in diameter and 526ft long. The pumps discharge into three 7ft 3in diameter concrete-encased steel pipes which converge into a covered concrete conduit, 11ft in diameter and 3220ft long, leading up the hill to the pump canal.

A Nuclear-Powered Submarine

The Bureau of Ships of the U.S. Navy has announced that a contract for the construction of the first nuclear-powered submarine has been awarded to the Electric Boat Company of Groton, Connecticut. Work on a nuclear power plant has been proceeding for more than a year. Several designs and several companies have been involved; including the Westinghouse Electric Corporation, working in co-operation with the Argonne National Laboratories and the General Electric Company. A "dry-land model" of the power plant is reported to have been assembled at the installation of the Atomic Energy Commission at Arco, Idaho. In its most recent report the Atomic Energy Commission had mentioned the construction of buildings and facilities in connection with work on two prototype submarine reactors. It has been estimated that the cost of developing a nuclear power plant for a submarine would be about 26,000,000 dollars. In April, when President Truman sent to Congress his 60,670,000,000 dollar military budget for the 1952 fiscal year, it was said that the budget included the amount of 29,500,000 dollars for the atomic submarine. There has been no indication of the size or capabilities of the craft. The most recent estimate regarding the date for completion of a nuclear-powered submarine is late 1953 or early 1954, but there have been suggestions that work is proceeding ahead of schedule.

"Dieselisation" of American Railways

The "dieselisation" programme of the American railways has progressed to the point where considerably more than one-half of the service performed by the carriers now is done by diesel locomotives. According to data compiled by the Association of American Railroads, diesel-electric locomotives in May of this year accounted for 52 per cent of the gross ton-miles in freight service, 63 per cent of the passenger train car-miles and 67 per cent of the yard shunting engine hours. At present nineteen of the so-called "Class 1" railways own no steam locomotives at all. With some 175 to 200 diesel-electric locomotives being put into operation each month, the time appears to be not far distant when virtually no railway service in the United States will be performed by steam locomotives.

French Engineering News

(From our French Correspondent)

Work is now in progress on the world's first electricity plant using the difference in temperature of sea-water at different levels as a source of power. It is being built at Abidjan and, if all goes well, should be completed in two years. The completion of this 3500kW plant will depend, however, on the sinking of a shaft to a depth of 420m at Port-Bouet.

Abidjan was chosen as the site of the first plant following successful experiments held at Brest. Experiments with sea-water have, of course, been carried on for well over twenty-five years. The difference in temperature between the cold water and the top surface water is about 20 deg. Cent., which is considered quite satisfactory.

The two conduits feeding the turbines will pass through a vacuum evaporator in which the water will boil. The turbines will be driven by the vapour, which will be condensed in a condenser cooled by the water at the low temperature drawn from the sea bed.

Sinking the cold water conduit is the main problem and the successful completion of the plant depends on this work. If it is successful the £1,000,000 installation will be completed and plans will then be drawn up to enlarge the plant. Because the Abidjan plant is still considered something of an experiment it has been planned on a relatively small scale. It will be greatly enlarged if it succeeds.

* * *

The first articulated coach to be used on the Paris Metro has been delivered. The new coaches are of welded construction throughout.

A train of three coaches, two second and one first-class, can carry 257 passengers, 193 standing. Such a train will weigh about 50 tons and will be driven by four 90 h.p. motors. The first of these new trains will come into service shortly and it is hoped that by 1961 some 100 trains will be running.

* * *

The sixth and last turbo-alternator set at Genissiat has now been brought into service. It will add 65MW to the installed capacity, bringing the total to 390MW (see THE ENGINEER, December 8, 1950).

* * *

The Bugatti works at Molsheim has been reopened and is now building an eight-cylinder, 19 h.p. car somewhat similar in design to the firm's 1939 model. The new Bugatti will have a top speed of 150km an hour. The works was closed in 1940, and requisitioned by the Germans. The plant was gradually dismantled, but since 1945 reconstruction work has been in progress.

* * *

The hydro-electric scheme on the Doustre at Marcillac has just been completed for Electricité de France. The Doustre is a tributary of the Dordogne, in the Massif Central; it has been developed by building an arch dam and diversion works leading to a power station of 30MW installed capacity, which discharges into the Chastang reservoir on the Dordogne.

The arch dam at Marcillac is 45m high, 8·75m wide at the base and 2·50m wide at the crown. It is 183m long. The intake works are situated 1200m from the barrage; the tunnel is 4700m long. The two vertical axis turbo-alternator sets in the power station operate under a head of 234m. The generator voltage is increased from 15kV to 90kV for transmission.

* * *

A sum of 8 milliard dollars is to be spent in developing French Union territory in Africa, south of the Sahara. According to the O.E.E.C. report just published, the development programme will last until 1955, with the objects of making known the resources of each territory and ensuring their most economic use; improving and extending basic facilities, especially communications, and improving the living conditions of local populations. The report emphasises the importance of as rapid a development as possible both to these regions and to world economy.

Industrial and Labour Notes

Quality in Mass Production

The Anglo-American Council on Productivity has announced the departure for the U.S.A. this week of a specialist team which is to study inspection methods in American mass production plants. The team is under the leadership of Mr. Leonard Sollis, managing director of the Highfield Gear and Engineering Company, Ltd., Huddersfield. Its joint secretaries are Mr. E. D. van Rest, of the National Physical Laboratory; and Dr. John Barnett, technical manager and chief inspector of Thorn Electrical Industries, Ltd.

Before leaving, members of the team spent some days touring various works in this country. In the U.S.A. it is proposed to examine inspection methods applicable to raw materials, semi-raw materials and finished articles. In particular, the team will give its attention to the function exercised by inspection in the organisation of industry at large. In its report it is expected that reference will be made to such matters as the status of inspection departments, the bearing of inspection on testing, the application of automatic jigs and fixtures, and the development of electronic tests.

Output of the Engineering Industries

In the course of a speech last week at the annual banquet given by the Lord Mayor to the bankers and merchants of the City of London, the Chancellor of the Exchequer, Mr. Hugh Gaitskell, referred to the magnificent way in which in recent years the engineering industries had responded to the increasing demands made upon them. To-day, however, the Chancellor said, the continued expansion of those industries was limited, and even the maintenance of their present production was threatened by a shortage of steel and, to some extent, of other metals. One of the great contributions that could be made to this country's economic situation would be a large increase in the amount of steel available, a matter which Mr. Gaitskell said that he emphasised in his recent talks in Washington.

But, the Chancellor went on, however successful this country was in getting increased amounts of steel, he doubted if in the near future the total engineering output could be increased sufficiently to accommodate all the additional demands on it. The defence programme, he stated, was expanding rapidly, and at the same time there must be an increase in the volume of engineering exports. That, the Chancellor observed, could only be achieved at the cost of a cut in home investment. He recalled that a number of steps had been taken, both in the Budget and before and since, to bring that cut about, and he suggested that some of those steps would become more effective as time went on. But the Chancellor said he doubted if they would be sufficient, and thought that further action, through direct controls and, as far as practicable, through credit restriction, would be required.

Labour Administration in the Colonies

The Secretary of State for the Colonies, Mr. Griffiths, presided, on Friday last, at the closing session of a conference in London of heads of labour departments and senior officers concerned with trade union affairs in the Colonies. The conference, which lasted a fortnight, was attended by thirty officials from twenty different territories, and made a comprehensive review of labour administration in the Colonies.

It is stated that the need for industrial harmony in carrying out plans of economic development and as a permanent social factor in Colonial progress was one of the conference themes. Careful consideration was given to ways and means, not only for resolving industrial disputes when they arose, but also for encouraging all methods of consultation and co-operation between employers and workers which could help to produce an atmosphere conducive to industrial peace and assist in establishing good labour relations. Other matters discussed at the conference were the functions of labour departments in giving guidance to the trade union movement in the Colonies, and education and training which could contribute to the development of sound and responsible trade unionism.

The Colonial Office says that consideration was also given to the general problems of social security in the territories represented at the conference. Improvements to existing schemes of workmen's compensation were discussed, and difficulties associated with the future development of such measures as old age pension schemes and unemployment insurance were examined. Finally, attention was directed to the serious shortage of skilled craftsmen in many areas, especially in the African territories, and to the problems related to technical training and apprenticeship schemes.

European Steel Production

The "Quarterly Bulletin of Steel Statistics," published by the United Nations Economic Commission for Europe, includes figures which indicate the trend of steel production in European countries, and also gives details as to the production and consumption of steelmaking materials. During the first six months of this year crude steel production, in the sixteen European countries from which information has been obtained, was at an annual rate of 59,862,000 metric tons, a rate 10 per cent higher than that which was achieved in 1950.

The annual output rate increased during the first half of this year in almost every country in Europe except the United Kingdom, where production remained at the 1950 level. The upward trend was particularly noticeable in Belgium, Luxemburg, the Saar and Italy. The "Bulletin" points out, however, that it is doubtful whether in the second half of this year Europe will succeed in maintaining the same rate of steel production.

The statistics of trade in raw materials show that there has been a substantial increase in the iron ore imports of Belgium and Luxemburg, and consequently increased ore exports from France, which is the principal supplier to the two aforementioned countries. Imports of scrap into Italy also increased in the first half of this year. Germany's scrap exports, however, declined considerably, a fact which is reflected by the reduced quantities made available from that country to the United Kingdom.

The Collection of Statistics

The United Nations Economic Commission for Europe has recently organised a conference of European statisticians, which has been discussing technical problems connected with the compilation of statistics of industry and external trade. The principal matter on the conference agenda was the possibility of bringing into general use a uniform international commodity classification which was adopted about a year ago by the European Statistical Commission. The conference felt that the complete adoption of this classification would mark an important step towards the more effective comparison of the trade statistics of different countries. The conference has also been discussing methods of compiling index numbers of industrial production and of organising industrial censuses. Here again, it has been suggested, the wide differences at present existing among the figures collected and published by different countries make it highly desirable that more uniform procedures should be agreed upon.

Lead Scrap Prices

The Non-Ferrous Metals Prices (No. 8) Order, 1951, which came into force on October 8th, permits a reduction of £5 a ton in the prices of remelted lead and lead scrap. The new prices per ton are: remelted lead, £160; scrap cable sheathing, £160; lead scrap other than cable sheathing, £156. The Ministry of Supply says that these reductions follow the recent decrease in the price of lead.

Energy for Industry

Last week-end the Institution of Incorporated Plant Engineers held a conference at Dunblane, Scotland, the principal theme of which was "Energy for Industry." At the opening session on Saturday morning, the president, Mr. D. Lacy-Hulbert, explained that the theme had been selected because of the country's need to see that sufficient energy of the right kind was constantly available to feed the ever-growing industrial production. Plant engineers were closely involved in the production and use of coal and electricity, which were two of the more important forms of energy, but Mr. Lacy-Hulbert went on to suggest that the third kind—human effort—was the most important. That, he said, was now an accepted fact, and industry was striving to use human effort more and more intelligently because only thus could it hope to prosper. All three kinds of energy, he added, were in short supply at present, but their respective uses were interdependent and were closely interwoven.

It was interesting to note, Mr. Lacy-Hulbert continued, that the annual national wages bill was now between five and ten times as much as it would cost to buy this country's yearly coal output, and as the coal lay freely in the ground, much of the price of coal was itself wages. That, he claimed, indicated how much more expensive was human effort than coal. Looking at it another way, it was necessary in a year to save about 120 tons of coal to equal the financial saving of one man's wages. In terms of electricity, Mr. Lacy-Hulbert asserted, a 60 h.p. motor would have to be eliminated. In most industries, he observed, it was much easier to economise in the man than the 120 tons of coal a year, and that was what was taking place. Expressed more correctly, it meant that the same manpower, through better production methods, was giving a greater output. As there was virtually no unemployment to-day, it was only by that continued economy in human effort that production could increase, a matter which, Mr. Lacy-Hulbert urged, was imperative if we were to thrive as a nation and also cope with the rearmament programme.

The balance of energy for industry, Mr. Lacy-Hulbert commented, had entered a very serious turning point in which rising productivity, driven forward by economic incentive, occupied the inside lane. In the outer lanes, coal and electricity availability were falling fast behind and must be spurred on to keep abreast. It was the ever-widening gulf between demand and supply which would have to be closed if we were to continue our economies in human effort and maintain full employment with all that that meant to us as an industrial nation.

Conference of Engineering Librarians

The Library Association is holding an informal conference on Friday, November 23rd, beginning at 11 a.m., at Chaucer House, Malet Place, London, W.C.1, of librarians working in the field of engineering. The purpose of the meeting is to discuss the Library Association working party's interim report on the "Co-operative Provision of Books, Periodicals and Related Material in Libraries." This report outlines a plan to ensure complete coverage of useful material in the libraries of this country, and members of the working party are anxious to hear the views of as many librarians as possible regarding the proposals. All librarians who are interested are invited to attend and those who wish to do so and have not yet received an invitation are asked to write to the Secretary of the Library Association, Chaucer House, Malet Place, London, W.C.1, from whom copies of the report can be obtained.

Notes and Memoranda

Rail and Road

SOUTH LONDON TRAM CONVERSION SCHEME.—Stage V of South London's tram conversion scheme was effected on October 6th. Seven more tram routes were replaced by new bus routes. The five stages of the conversion scheme which have now been completed have resulted in the withdrawal of 414 tramcars and their replacement by 487 buses.

INTERNATIONAL ROAD FEDERATION.—The International Road Federation states that Sir Donald St. Clair Gainer, K.C.M.G., is to become its chief executive on October 15th, on his retirement from the Foreign Office. Sir Donald, who is at present adviser on German affairs, has throughout his service taken a keen interest in all matters relating to transport and road-building.

C.P.R. ROLLING STOCK ORDERS.—The Canadian Pacific Railway has recently placed orders, valued at 50,000,000 dollars, for locomotives and rolling stock. The equipment includes fifty diesel-electric locomotives, thirty-eight of which will be used to complete the change-over to diesel traction of the freight and passenger services between Calgary and Revelstoke. The contracts also provide for 4250 new freight cars of various descriptions.

Miscellanea

THE LATE MR. W. T. TOLHURST.—We have learned with regret of the death of Mr. William Thomas Tolhurst, a director of W. G. Allen and Sons (Tipton), Ltd., Tipton, Staffs, which occurred suddenly on September 24th. Mr. Tolhurst had been associated with the company for thirty-nine years, having been works manager since 1919 and a director since 1943.

CHICAGO INTERNATIONAL TRADE FAIR.—It has been announced recently that the Chicago International Trade Fair is to become a permanent institution. The first fair was held in August, 1950, and was attended by over 250,000 people. Next year, the fair will take place at Navy Pier, Chicago, from March 22nd to April 6th. The representative in the United Kingdom for the Chicago International Trade Fair is Mr. A. P. Wales, whose office is at 16, Shelton Street, London, W.C.2 (telephone, Temple Bar 2972, Extension 14).

PARCELS CONTAINING NUTS, BOLTS, &C.—The Post Office urges senders of parcels containing nuts, bolts, small machine parts, &c., to use hessian as an inner wrapping. Experience has shown that because of their very heavy weight, enclosures of this kind are liable to burst through all but the strongest wrapping. The use of extra strong wrapping, such as hessian, will reduce to the minimum the risk of loss through enclosures escaping from parcels and will save the time of Post Office staff who are at present called upon to repair many parcels.

ENGINEERING INDUSTRIES ASSOCIATION LONDON REGIONAL DISPLAY.—The fourth London Regional display of the Engineering Industries Association will be held at the Royal Horticultural Society's new hall, Greycoat Street, London, S.W.1, on October 16th and 17th next. In addition to the display of member firms' products and processes there will be this year an exhibition at which main contractors can show blueprints, prototypes and samples of work which they wish to put out to sub-contract. The products and work of some 130 member firms will be displayed.

NATIONAL DIPLOMA IN AGRICULTURAL ENGINEERING.—The first examinations for the National Diploma in Agricultural Engineering, instituted by the Institution of British Agricultural Engineers, were held recently at Writtle, Essex, and Glasgow. The following candidates have been successful in passing the final examination for the diploma:—Mr. R. T. Stirling, Mr. C. J. Swan, Mr. W. C. Wilson (all with distinction), Mr. C. Cowley, Mr. P. King, Mr. K. E. Morgan, Mr. J. A. Patterson, and Mr. R. R. Robertson. All of them are now entitled to use N.D.Agr.E. as a professional qualification.

NIMONIC ALLOYS.—A recent publication, issued by Henry Wiggin and Co., Ltd., Wiggin Street, Birmingham, presents, in a convenient form, all the available information on the Nimonic series of alloys. In addition to tables of physical and mechanical properties, a useful series of graphs gives design data of these nickel-chromium alloys at various temperatures; in this section appear some data only recently determined as a result of the long-time creep test. Other sections summarise the heat-treatment and acceptance creep tests laid down in the appropriate D.T.D. Specifications. A list of typical applications of these nickel-chromium alloys operating at elevated temperatures is included.

SWEDEN'S FUEL SUPPLIES.—A ten-year programme for Sweden's fuel supplies, which has been prepared by a committee of experts, has recently been submitted to the Minister of Commerce. In addition to the continued extension of hydro-electric schemes, the programme recommends that peat production should be stepped up to an annual output of 4,000,000 tons by 1960, while the annual production of oil from the shale oil works in Central Sweden is estimated at 700,000 tons in about ten years' time. Other recommendations include more fuel research and increased conversion to modern fuel equipment in factories and houses. It is estimated that the cost of the programme is likely to be over £103,000,000.

TIN ANALYSIS.—A booklet entitled "Sampling and Analysis of Tin Ingots," has recently been published by the Tin Research Institute, Greenford, Middlesex. Standard tin, as deliverable on the London Metal Exchange, is guaranteed to contain a minimum of 99·75 per cent tin. Special grades of a purity of 99·99 per cent and higher are also available. This booklet is published to meet the needs of chemists, who for special purposes wish to determine the actual amounts of each different impurity in refined ingots containing 99·75 per cent of tin or over. The procedures described cover the following impurities:—Lead, copper, bismuth, iron, aluminium, zinc, nickel, cobalt, arsenic, antimony and sulphur. A sampling procedure is also suggested.

N.C.B. UNIVERSITY SCHOLARSHIPS.—Forty-five men in the coal-mining industry and twenty-three from outside it, have been offered National Coal Board university scholarships in mining engineering and allied subjects. This is the fourth successive year in which the Board has offered 100 scholarships, divided between men in the industry and external candidates who have taken their Higher School Certificates or subjects at advanced level in the General Certificate of Education. Most awards are for students to read mining engineering, but a few are for mechanical and electrical engineering and fuel technology. After graduation, students will undergo practical training and advanced technical instruction, as well as tuition in the fundamentals of management, to prepare them for posts of responsibility in the industry. The scholarships cover the whole cost of education and, in addition, there is a maintenance allowance which may amount to £300 a year.

FUEL RESEARCH CONFERENCE REPORT.—In 1946, the British Commonwealth Scientific Conference, which was convened to consider the best means of ensuring the fullest possible collaboration between the Government scientific organisations of the Commonwealth and Colonial Territories, expressed the view that specialist conferences should be called at intervals to discuss in detail collaboration in certain scientific fields. In accordance with this recommendation a specialist conference on fuel research was held in London in July, 1950, advantage being taken of the presence in this country of a number of Commonwealth delegates to the World Power Conference. The report of that conference, containing not only the recommendations, but also a summary of the discussions at the various sessions, has now been published by H.M. Stationery Office. The conference discussed existing facilities for fuel research in the Commonwealth and the possibilities of improving such facilities and of augmenting present arrangements for liaison, exchange of staff and exchange of information. Special attention was given to ensuring collaboration in selected fields of fuel research, including coal preparation, coke production, gasification and fuel efficiency. Educational and training facilities in fuel science and technology were also reviewed and suggestions were made for improving such facilities. The conference recommended the establishment of a Commonwealth Committee on Fuel Research to facilitate and implement liaison, collaboration and exchange of information.

Contracts

THE ENGLISH ELECTRIC EXPORT AND TRADING COMPANY, Ltd., and Metropolitan-Vickers Electrical Export Company, Ltd., announce that they have negotiated a contract valued at £1,000,000 for the hydraulic, mechanical and electrical equipment of a new power station, to be built by the Hidro-Electrica do Zezere, S.A.R.L., at Cabril, on the River Zezere, about 120 miles north-east of Lisbon. The power station will be equipped with two hydro-electric generating units of 73,000 maximum h.p. each, together with ancillary switchgear and transformer equipment, all of which will be manufactured in Great Britain.

Personal and Business

SIR CECIL WEIR, K.B.E., has joined the board of the Pyrene Company, Ltd., 9, Grosvenor Gardens, London, S.W.1.

MR. W. B. ROBSON, A.M.I.E.E., has been appointed general manager of Cantie Switches, Ltd., Bromborough, Cheshire.

MR. REGINALD F. NORRIS has been appointed general manager of D.M.M. (Machinery), Ltd., 119, Victoria Street, London, S.W.1.

DUNLOP, Ltd., states that Mr. G. B. Williamson, M.I.Mech.E., a director of the Dunlop cotton mills, Rochdale, has retired at his own request.

JOHN GARRINGTON AND SONS, Ltd., Darlaston, Staffs, states that, with Board of Trade approval, its name has been changed to Garringtons, Ltd.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that the telephone numbers of its Middlesbrough office are now Middlesbrough 2838 and 43569.

MISS ROSEMARY GARLAND has been appointed Press officer of the Glass Manufacturers' Federation, 17, Manchester Street, London, W.1 (telephone, Welbeck 0461).

THE COLONIAL OFFICE announces that Sir John Hathorn Hall, who is retiring from the Governorship of Uganda, is to join the Colonial Development Corporation as a part-time member.

MR. S. C. GREATRIX has taken over administrative control of all branches of Marbello and Durus, Ltd., and the Concrete Case Hardening Company, Ltd. His address is Crescent Wharf, Birmingham, 1.

LONDON TRANSPORT states that Mr. A. C. Newby, formerly planning engineer at the Charlton works, has been appointed assistant works manager (trams and trolleybuses) in the department of the chief mechanical engineer (road services).

MATTHEW HALL AND CO., Ltd., 26–28, Dorset Square, London, N.W.1, announces that Mr. S. Kindler, A.M.I.San.E., has been appointed a director and that Mr. A. C. McCarthy, A.M.I.San.E., has rejoined the staff of the company.

THE CANADIAN PACIFIC RAILWAY announces the appointment of Mr. C. A. Colpitts, of Montreal, as assistant chief engineer in place of Mr. R. A. Emerson, who has recently become chief engineer. Mr. John E. Armstrong, Junr., has succeeded Mr. Colpitts as engineer of track.

MR. F. M. OWNER, C.B.E., M.I.Mech.E., F.R.Ae.S., has been appointed deputy chief engineer of the de Havilland Engine Company, Ltd. His office is at the headquarters of the company's engineering division at Stag Lane, Edgware, Middlesex. Mr. W. F. Shaylor has been appointed commercial manager of the company. His address is Stonegrove Factory, Edgware.

Launches and Trial Trips

BRITISH PIONEER, motor tanker; built by Blythswood Shipbuilding Company, Ltd., for the British Tanker Company, Ltd.; length between perpendiculars 463ft, breadth 61ft 6in, depth moulded 34ft, deadweight 12,400 tons; twenty-seven cargo oil tanks, two pump rooms, four steam cargo oil pumps; Kincaid-Burmeister and Wain four-cycle, single-acting, diesel engine; six cylinders, 740mm diameter by 1500mm stroke, 3200 b.h.p., two horizontal multi-tubular boilers, speed 12½ knots. Trial, September 18th.

LONDON VICTORY, motor tanker; built by the Furness Shipbuilding Company, Ltd., for London and Overseas Freighters, Ltd.; length between perpendiculars 525ft, breadth moulded 71ft, depth moulded 39ft 3in, deadweight 18,200 tons on 30ft 6in draught; N.E.M.-Doxford oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6800 b.h.p. at 119 r.p.m. Launch, September 18th.

WESTERN COAST, cargo vessel; built by the Goole Shipbuilding and Repairing Company, Ltd., for Coast Lines, Ltd.; length 220ft, breadth 35ft, depth 21ft, deadweight 1235 tons; British Polar oil engine, 1140 b.h.p. at 250 r.p.m., speed 12 knots. Trial, September 25th.

BOLLSTA, motor tanker; built by Harland and Wolff, Ltd., for Fred Olsen and Co., Oslo; length between perpendiculars 580ft, breadth moulded 73ft, depth moulded 42ft 6in, deadweight 24,000 tons; twenty-seven cargo oil tanks, two pump rooms, steam deck machinery; Harland-Burmeister and Wain, single-acting, two-cycle, opposed-piston oil engine, seven cylinders, 750mm diameter by 2000mm combined stroke, 110 r.p.m., two single-ended cylindrical, multi-tubular boilers. Trial, October 6th.

British Patent Specifications

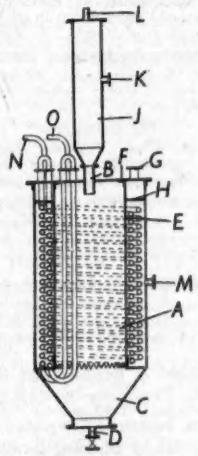
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.

HEAT EXCHANGERS

657,079. December 29, 1948.—Heat Exchangers for Liquors, Yorkshire Tar Distillers, Ltd., National Employers House, Leeds, 1, Yorkshire (*Inventor: John Arthur Stocks*).

The invention relates to heat exchangers for use in the recovery of sensible heat from liquors, such as coal tar, pitch, bituminous residues and the like materials which deposit sediment. As shown in the drawing, the apparatus comprises a chamber *A* having an inlet *B* at the top. The lower end *C* of the chamber is hopper-shaped and is furnished with a valved outlet *D*, through which the sediment collecting in the chamber may be discharged, and an annular shell *E* within the chamber secured



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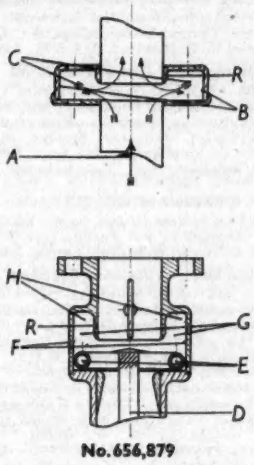
to the upper wall of the chamber at *F*. Between the shell and the walls of the chamber heat exchange elements in the form of tubular coils are located and an outlet *G* for the cooled liquid is provided at the top of the chamber. To promote the distribution of the liquid to be cooled the lower end of the shell is serrated. Further, to give an even flow of liquid past the heat exchange tubes, there is a grid *H* across the annular space above the tubes. Above the chamber and connected with its upper wall is a flash chamber *J* to permit gases or vapours to separate from the liquid before it enters the heat exchange apparatus. Liquid may be introduced into the chamber through an inlet *K*; vapour may escape through a port *L* at the top. Between the upper and lower extremities of the chamber is a bleed pipe *M* to enable the liquid to be drawn off at this point at a higher temperature than that which leaves by way of the outlet *G*. The cooling medium or the medium which is to be heated enters the coils by way of the pipe *M* leaves, having become heated in its passage through the coils, by way of the pipe *O*. By subjecting the ingoing hot liquor to a downward flow at a relatively slow velocity and thereafter abruptly causing it to flow in an upward direction, the suspended matter is deposited at the bottom of the apparatus clear of the heat exchange surfaces.—*September* 12, 1951.

INTERNAL COMBUSTION ENGINES

656,879. October 22, 1947.—Formation of Combustible Mixtures for I.C. Engines, Paul Calixte Lacoste, 45, Avenue Pierre Brosselette, Montrouge, Seine, France, and Andre Ader, 22, rue des Sablons, Paris, France.

The object of this invention is to improve the mixing of volatile fuel and air to the extent of eliminating the collection of fine drops of fuel which would otherwise create disadvantages arising from difficulties in correct lubrication of engine cylinders and unnecessary high fuel consumption, entailing high running costs and an exaggerated wear of engine cylinders and pistons. The accompanying drawings show a sectional view of a diffuser adapted to be inserted between a carburettor and an engine cylinder and a sectional view of a diffuser attached to a carburettor. In the upper view the arrow *A* indicates the direction of travel of the fuel and air in a duct connecting a carburettor to its engine. When the mixture reaches a chamber *B* it expands outwards, in a direction normal to the axis of the duct into a turbulency zone *C*, and is caused to whirl to create turbulence before it is finally sucked into the duct leading to the engine. In the lower view, a central diffusing fuel jet or nozzle *D* is shown, from which the mixture is projected fanwise on to a heater ring *E* in a diffusion chamber, which may be heated as desired. The mixture then travels upwards along vertical



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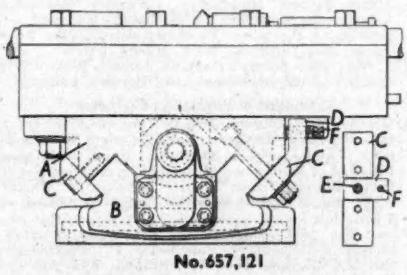
walls *F* of the diffusion chamber. In traversing the vertical walls *F* the mixture arrives at a turbulency zone *G*, created by the downward extending lip or rim *R*, whence it is adapted to saturate a porous mass *H*. Having been thus subjected to intimate mixing by a change of direction by the lip the mixture is passed, under the action of suction, into the duct leading into the engine cylinders without any danger of deposition of fuel in liquid form. The efficiency of mixing of fuel and air is such that unheated volatile liquid fuels other than petrol may be used for combustion purposes.—*September* 5, 1951.

MACHINE TOOLS

657,121. August 21, 1948.—Planing Machines, The Butler Machine Tool Company, Ltd., Westholme Road, Mile Thorn, Halifax, and Wilfred Alderson, of the company's address.

This invention relates to tool-box slides for planing machines and is particularly applicable to the vertical slides which must work with overhang and offset loads and are often swivelled. In the accompanying drawing, which shows an elevation of part of the vertical slide of a planing machine, tool-box constructed in accordance with the invention, *A* indicates the fixed slide, *B* the movable slide, *C* the keep plates and *D* the locking piece. It will be seen that the inner faces of both slides are made narrower than the outer faces and the V-shaped projections are



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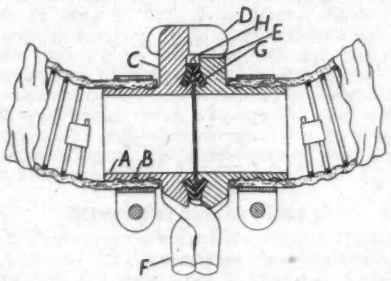
formed on the movable slide *B*. Each guide has a 90 deg. included angle and the keep plates are on the outside, each with its face at 90 deg. to the outer face of one of the guides. One of the keep plates can have a piece cut out of it as shown to form a space for a locking piece *D* bolted to the fixed slide *A* by the bolt and nut *E* and provided with an adjusting screw *F*, which can be used to apply pressure to give a solid nip for locking the movable slide without disturbing the keep plate. In manufacture the V-shaped projections and recesses on the mating slides are machined and ground in the ordinary way, after which the slides are placed in position one within the other in a slideway grinder and a finishing cut ground across the faces of both slides at one operation. A flat keep plate is then bolted or screwed to the fixed slide and it has been found in practice that although theoretically there would be no working clearance, a rigid, but free-moving slide, results.—*September* 12, 1951.

RAILWAY ENGINEERING

657,244. March 3, 1949.—Vacuum Hose Couplings, Westinghouse Brake and Signal Company, Ltd., and Aloysius Graham Brackenbury, both of 82, York Way, King's Cross, London, N.1.

The invention relates to hose couplings of the "Clayton" type, as used on railway vehicles for coupling together the vacuum brake pipe between successive vehicles in a train. The coupling heads comprise a hollow cylindrical body portion *A*, over which is fitted the flexible hose. Integral with one end of the body is a flange portion *C*, having a projecting rectangular lug *D*, one vertical side of which forms one wall of an adjacent rectangular slot *E*, adapted to receive the corresponding lug of the coupling head forming the other



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half of the coupling. Diametrically opposite to the lug *D* and the slot *E* a projecting horn *F* formed with a goose-neck for engagement with the corresponding horn of the mating coupling head, as illustrated, is provided. The cylindrical body portion *A* extends slightly beyond the flange portion *C* and is provided with a groove *G*, which embraces a flexible gasket or sealing member *H*. In order to couple the two heads they are presented to each other so that the goose-neck of one coupling horn engages with that of the other. The lug on each head is then inserted into the co-operating slot in the other head. The drawing illustrates a completed joint.—*September* 12, 1951.

BEARINGS AND SUPPORTS

657,080. January 11, 1949.—Plain Bearings, The Glacier Metal Company, Ltd., 368, Ealing Road, Alperton, Wembley, Middlesex, and William Henry Tait, of the company's address.

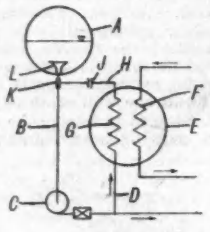
The invention has for its object the provision of an improved bearing structure or bearing facing adapted for operation without the use of an intermediate separating film of oil or other lubricant. For the production of a bearing bush for use with a steel shaft or journal, poly-tetra-fluoro-ethylene in powder form and silver in powder form are mixed in the ratio of five parts by volume of silver to one part by volume of the synthetic compound, both powders being sufficiently fine to pass through a 100 mesh screen. The mixed powder is then cold-pressed in a suitable die, to compact it into a moulded but "uncured" form sufficiently coherent for handling. This moulded form is then sintered in an atmosphere of cracked ammonia, forming a mixture of nitrogen and hydrogen by the dissociation of ammonia, at a temperature of about 360 deg. Cent. for about one hour. While still hot the sintered body is pressed in a mould to the exact final shape desired, thereby producing a bush having a duplex structure consisting of silver and poly-tetra-fluoro-ethylene in the form of interlaced sponges of fine texture, and of any desired size or shape. Such a bush may be utilised in place of any self-lubricating porous bush of the usual type. Methods of manufacturing thin-walled metal-backed bearings and thrust washers on similar lines are also described in the specification.—*September* 12, 1951.

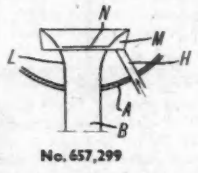
STEAM GENERATORS

657,299. January 28, 1948.—Steam Boilers, Tore Johannes Hedback, of Aktiebolaget Svenska Maskinverken, Sodertelje, Sweden.

This invention relates to water-tube boilers of the forced circulation type provided with downcomers leading from a water and steam drum to a recirculation pump. Its object is to provide improved means for compensating the fall in pressure in a downcomer when the boiler or generator is subjected to heavy or abnormal demands for steam and to prevent vaporisation or steam formation in the downcomer. In the upper drawing a steam

and water drum *A* of a water-tube boiler and *B* a downcomer, connected at its lower end to the suction side of a circulating pump *C* is shown. A branch pipe *D* starts from the pressure side of the circulating pump and non-return valve, and passes through a cooler or heat exchanger *E* which may consist of a separate vessel having an additional cooling coil *F* for liquid or gas, or it may be a feed-water container. The coils are provided with an adjusting or closing member for varying the quantity of circulating liquid through the cooler *E* within the quantities desired. The coil *G* continues in a pipe *H*, opening via a throttling member *J* directly into a cool water distributor *K*





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in the downcomer *B* some distance below the drum. A modified form of cool water distributor placed in the lower part of the drum embodied in the outflow funnel *L* of the drum is shown in the lower drawing. The distributor includes an annular compartment *M* communicating with the downcomer through a space or slit *N*, the cooled-down circulating water, supplied from the conduit *H*, being led directly through the drum to the annular compartment. By the arrangements described, a decrease in temperature with, in some cases, an increase of pressure is created in the downcomer, so that with varying withdrawals of steam the safety of operation is not reduced.—*September* 19, 1951.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Association of Building Technicians

Mon., Oct. 15th.—LONDON BRANCH: Denison House, Vauxhall Bridge Road, S.W.1, Discussion on "The Challenge to the Building Industry," 7.15 p.m.

Association of Supervising Electrical Engineers

To-day, Oct. 12th.—BRISTOL BRANCH: Grand Hotel, Bristol, "Energy from the Atom," A. F. Possnett, 7.30 p.m.——NOTTINGHAM BRANCH: Electricity Showrooms, Smithy Row, Nottingham, "Relays and Remote Control," W. L. Stern, 7.30 p.m.

Engineering Legal Society

Wed., Oct. 17th.—Holborn Restaurant, London, W.C.1, "The Development of Inventions Act, 1948, and the Work of the National Research Development Corporation," The Rt. Hon. The Earl of Halsbury, 6.30 p.m.

Illuminating Engineering Society

To-day, Oct. 12th.—BIRMINGHAM CENTRE: Imperial Hotel, Temple Street, Birmingham, Chairman's Address, R. A. Lovell, 6 p.m.

Fri., Oct. 19th.—HUDDERSFIELD GROUP: Technical College, Queen Street South, Huddersfield. "Light, Colour and the Stage," E. E. Faraday, 7.15 p.m.

Institute of British Foundrymen

To-day, Oct. 12th.—LONDON BRANCH: Second Annual National Works Visits Day.

Sat., Oct. 13th.—W. RIDING OF YORKSHIRE BRANCH: Technical College, Bradford, "Brains Trust," 6.30 p.m.

Institute of Fuel

Tues., Oct. 16th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, S.W.1, "Combustion Processes in Engines," F. H. Garner, 5.30 p.m.

Institute of Industrial Administration

Tues., Oct. 16th.—LONDON CENTRE: Management House, Hill Street, W.1, "The Principal Problems of Financial Incentive Schemes," H. A. Randall and J. I. Anderson, 7 p.m.

Institute of Metals

Mon., Oct. 15th.—SHEFFIELD LOCAL SECTION: The University, St. George's Square, Sheffield, "Radioactive Tracers in Metallurgy," H. M. Finniston, 7.30 p.m.

Wed., Oct. 17th.—Park Lane Hotel, Piccadilly, London, W.1, General Discussion, "Metal Economics," 10 a.m., 4, Grosvenor Gardens, S.W.1, Conversazione and Exhibition, 8 p.m.

Institute of Navigation

Fri., Oct. 19th.—Royal Geographical Society, 1, Kensington Gore, S.W.7, Presidential Address, "Navigation and the Shipping Industry," Sir Robert Watson-Watt, 3 p.m.

Institute of Petroleum

Wed., Oct. 17th.—STANLOW BRANCH: Grosvenor Hotel, Chester, "World Petroleum Developments," C. A. P. Southwell, 7.30 p.m.

Institution of British Agricultural Engineers

Tues., Oct. 16th.—Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C.2, Presidential Address, F. E. Rowland, M.I.E.E., 2.30 p.m.

Institution of Chemical Engineers

Sat., Oct. 20th.—N.W. BRANCH: College of Technology, Manchester, "Chemical Engineering and the Future," Sir Harold Hartley, 3 p.m.——MIDLANDS BRANCH: The University, Edmund Street, Birmingham, "Recovery of Sulphur Dioxide from Effluents Obtained in Sulphuric Acid Manufacture," L. Moller, 3 p.m.

Institution of Civil Engineers

Thurs., Oct. 18th.—Great George Street, London, S.W.1, "Gravel Compaction and Testing and Concrete-Mix Design at London Airport," H. Smith, 5.30 p.m.

Institution of Electrical Engineers

To-day, Oct. 12th.—N.E. STUDENTS' SECTION: King's College, Newcastle upon Tyne, "The Development of Power Cables," G. F. Cundall, 6.30 p.m.

Mon., Oct. 15th.—LONDON STUDENTS' SECTION: Savoy Place, Victoria Embankment, W.C.2, "Keeping Electricity Safe," K. C. Pounds, 7 p.m.

Tues., Oct. 16th.—Savoy Place, Victoria Embankment, W.C.2, Discussion on "The "j" Operator Method of Calculation—When and How Should it be Introduced?" opened by A. W. Gillies, 6 p.m.——N. MIDLAND CENTRE: Lighting Service Bureau, 24, Aire Street, Leeds, 1, "Modern Developments in Electric Welding," H. G. Taylor, 6.30 p.m.

Wed., Oct. 17th.—RADIO SECTION: Savoy Place, W.C.2, Chairman's Address, D. C. Espley, 5.30 p.m.——SCOTTISH CENTRE: Heriot-Watt College, Edinburgh, Chairman's Address, 7 p.m.

Institution of Locomotive Engineers

Wed., Oct. 17th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, S.W.1, "The Inspecting Engineer's Contribution to Railway Economy," J. S. Tritton, 5.30 p.m.

Institution of Mechanical Engineers

To-day, Oct. 12th.—N.E. BRANCH, GRADUATES' SECTION: Head, Wrightson and Co., Ltd., Teesdale Ironworks, Thornaby-on-Tees, Stockton, "Materials Testing," M. Milne, 7 p.m.

Mon., Oct. 15th.—MIDLAND BRANCH, GRADUATES' SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "An Introduction to Furnace Design," J. W. Bassett, 6.30 p.m.——DERBY A.D. CENTRE: Midland Hotel, Derby, "Independent Rear Suspension," Donald Bastow, 7 p.m.——SCOTTISH A.D. CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Experiences During Twenty Years of Oil Engine Development," C. B. Dickson, 7.30 p.m.

Tues., Oct. 16th.—YORKSHIRE BRANCH, GRADUATES' SECTION: College of Commerce and Technology, Sheffield, "Electric Resistance Strain Gauges and Their Application to Rolling Mill Instruments," R. F. Bowler, 7 p.m.

Wed., Oct. 17th.—MIDLAND BRANCH, GRADUATES' SECTION: Craven Arms Hotel, High Street, Coventry, "The Combustion Process in High-Speed Reciprocating Engines," J. R. Willetts, 7.30 p.m.

Thurs., Oct. 18th.—N.E. BRANCH, GRADUATES' SECTION: Visit to Pyrotenax, Ltd., Hebburn-on-Tyne, County Durham, 6 p.m.——N.W. BRANCH: Engineers' Club, Albert Square, Manchester, "Further Mechanical Aids for the Foundry," A. S. Beech, 6.45 p.m.——YORKSHIRE BRANCH: The University, Leeds, "Stationary Gas Turbines," F. R. Harris, 7 p.m.

Fri., Oct. 19th.—Storey's Gate, St. James's Park, S.W.1, Address by the President, A. C. Hartley, 5.30 p.m.

Institution of Production Engineers

Mon., Oct. 15th.—DERBY SECTION: School of Art, Green Lane, Derby, "Designing for Welding," F. Brooksbank, 7 p.m.——N.E. SECTION: North of England Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle upon Tyne, "Increase of Productivity by Machine Shop Practice," A. Cameron, 7 p.m.

Tues., Oct. 16th.—MANCHESTER GRADUATE SECTION: College of Technology, Manchester, 1, "Productivity and the Machine Tool," N. Stubbs, 7.15 p.m.——WESTERN SECTION: Grand Hotel, Bristol, "Work Measurement and Results of Research Survey," D. J. Desmond, 7.15 p.m.——WOLVERHAMPTON GRADUATE SECTION: Willenhall Evening Institute, Stafford Street, Willenhall, A Film and Talk entitled "Hard Metal," 7.30 p.m.

Wed., Oct. 17th.—BIRMINGHAM SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "The History and Manufacture of Watches," A. W. Marshall, 7 p.m.——COVENTRY SECTION: Geisha Cafe, Hertford Street, Coventry, "Factory and Plant Development Costs," G. T. Verrall, 7 p.m.——COVENTRY GRADUATE SECTION: Hare and Squirrel Hotel, Cow Lane, Coventry, Douglas D. Davis Award—Part (A) Open Papers, 7.15 p.m.——EDINBURGH SECTION: North British Station Hotel, Edinburgh, "Some Aspects of a Factory Inspector's Work," Miss G. M. Mitchell, 7.30 p.m.

Thurs., Oct. 18th.—GLASGOW SECTION: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, "Diamonds in Industry," A. M. Livingston, 7.30 p.m.——LONDON SECTION: Brighton Technical College, Richmond Terrace, Brighton, "A Symposium on Modern Metrology," C. O. Taylorson, D. F. Galloway and J. Loxham, 7 p.m.

Institution of Structural Engineers

Tues., Oct. 16th.—LANCASHIRE AND CHESHIRE BRANCH: Engineers' Club, Albert Square, Manchester, Chairman's Address, R. Gray, Films, "New Tyne Bridge," "Ford Works, Dagenham," 6.30 p.m.

Wed., Oct. 17th.—YORKSHIRE BRANCH: Great Northern Hotel, Leeds, Chairman's Address, A. Robb, 6.30 p.m.

Junior Institution of Engineers

To-day, Oct. 12th.—39, Victoria Street, Westminster, S.W.1, "Gas Distribution Engineering," C. D. Shann, 6.30 p.m.

Sat., Oct. 20th.—N.W. SECTION: Manchester Geographical Society, 16, St. Mary's Parsonage, Manchester, "Time Recording," W. J. Thompson, 2.30 p.m.

Liverpool Joint Chemistry Committee

Wed., Oct. 17th.—Grosvenor Hotel, Chester, "World Petroleum Developments," C. A. P. Southwell, 7.30 p.m.

Thurs., Oct. 18th.—Chemistry Lecture Theatre, The University, Liverpool, Symposium on "Chemical Microscopy," J. G. A. Griffiths, J. King and N. H. Hartshorne, 7 p.m.

Liverpool Metallurgical Society

To-day, Oct. 12th.—Electricity Service Centre, Whitechapel, Liverpool, "The Problem of the High Temperature Oxidation of Metals," A. Preece.

Manchester Association of Engineers

Fri., Oct. 19th.—Engineers' Club, Albert Square, Manchester, "Electrical Power Distribution in Factories," E. Jacks, 6.45 p.m.

Old Centralians

Mon., Oct. 15th.—Chez Auguste Restaurant, Frith Street, London, W.1, "The Late Silvanus Thompson," Sir Frederick Handley Page, 12.55 p.m.

Reinforced Concrete Association

Wed., Oct. 17th.—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Moving Forms for Concrete Construction," H. H. Broughton, 6 p.m.

Royal Aeronautical Society

Thurs., Oct. 18th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, S.W.1, "Modern Trends in Civil Airworthiness Requirements," Walter Tye, 6 p.m.

Sheffield Society of Engineers and Metallurgists

Mon., Oct. 15th.—The University Building, St. George's Square, Sheffield, "Radioactive Tracers in Metallurgy," H. M. Finniston, 7.30 p.m.

Society of Chemical Industry

Thurs., Oct. 18th.—ROAD AND BUILDING MATERIALS GROUP: Institution of Structural Engineers, 11, Upper Belgrave Street, London, W.1, "The Durability of Tar and Tarmacadam," A. R. Lee and E. J. Dickinson, 6 p.m.

Stephenson Locomotive Society

Sat., Oct. 13th.—N.W. CENTRE: Manchester Geographical Society, 16, St. Mary's Parsonage, Manchester, "The Furness Railway," W. A. Shillcock, 6.15 p.m.

Fri., Oct. 19th.—32, Russell Road, Kensington, London, W.14, "Brighton Locomotive Reminiscences," L. Billington, 6.45 p.m.

INSTITUTION OF PRODUCTION ENGINEERS.—The Institution of Production Engineers held its annual dinner at the Dorchester Hotel, London, on Tuesday, October 2nd. The guest of honour was Mr. W. R. Herod, Co-ordinator of the North Atlantic Treaty Defence Production. Major-General K. C. Appleyard proposed the toast of "The English Speaking Peoples." In his reply, Mr. Herod reviewed the progress being made in rearmament by the North Atlantic Treaty Organisation (N.A.T.O.) nations, and compared their potential power with that of Russia and its satellites. The twelve N.A.T.O. countries, he said, had a population of 340 millions compared with about 300 millions for the U.S.S.R. and its European satellites. They had three to four times the national income and four to five times the steel production and electric power. But, as compared with 1949, the Soviet Union had been reported to have increased its production in 1950 by some 23 per cent. Its crude steel production in 1950 was 27·3 million tons, its output of coal and lignite 260 million tons, that of crude petroleum 37·8 million tons, and of cement 10·2 million tons. Some 90 billion kWh of electric energy had been generated. The relative growth in the four years from 1947 to 1950 in the industrial production of the U.S.S.R. on a percentage basis had considerably exceeded that of the N.A.T.O. countries. The output of Western countries was now being, to some extent, restricted by shortage of raw materials. Temporarily the difficulty could be overcome by controls and allocations. But the long-run solution lay in positive action to develop a wider availability of basic materials. After Mr. Herod's response had been concluded, a presentation of Institution awards was made. Proceedings were brought to an end by the proposal by Mr. Burke, vice-chairman of Council of the Institution, of the toast of "The Guests," to which Sir Cecil Weir, lately Chairman of the Dollar Exports Board, responded.